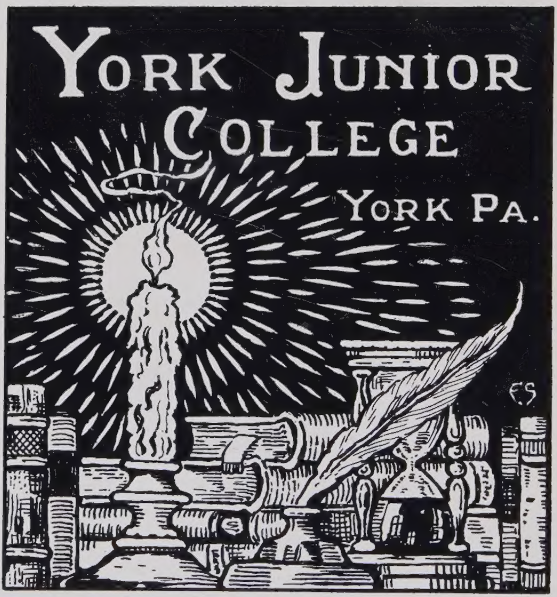
EINSTEIN'S RELATIVITY

D. J. McADAM



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EINSTEIN'S RELATIVITY

Silly + ~~Asinine~~

A CRITICISM

BY

D. J. McADAM

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EINSTEIN'S RELATIVITY

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CHAPTER I

PUBLIC INTEREST IN SCIENTIFIC DISCOVERIES

A scientific discovery, even a scientific theory, comes to have a certain fascination for many non-scientific people. The reasons for this are various. The optimist hails it as another triumph of human intellect or endeavor, or as perhaps the harbinger of better things for the world.

The poser, who affects wide reading and great learning, welcomes it as a new foundation upon which he may build his outre structures. The sensational writer for the paper or magazine startles his reader with impending calamity, or fills him with joyful hope of a millennium. Another dashes his hope mayhap by unloosing the pent up energy in the atom and blowing him up in the wreck of the world.

Then there are some who have, along with the rest of us, deep down in their heart, much joy that some one has driven a tunnel under the pedestal of a scientific king. If he comes down we all seem to come up somewhat.

The more Newton and Euclid didn't know the more we know. For instance, there is the fourth dimension. Three dimensions were good enough for our ancestors, but we live in a more progressive age. Besides another space dimension may be very useful to us. If we want to turn our left hand into the right, instead of using the scalpel and cutting the hand close to the skin of the palm and turning the rest of the hand particle by particle over a hinge at one side, as theory strictly requires, we can take our left hand out beyond the stars, or behind the barn, out of sight, or wherever fourth dimension is, and bring it back a perfectly good right hand.

If we are in need of Liberty Bonds and they are in a chrome-steel safe, when we become expert in fourth dimension, we just lift them out from the top of the safe, to the surprise and prison sentence of the cashier. If we want to see the back of our head, we just make use of one of the non-Euclidean spaces. It is said that the cluster of stars called Coma Berenices is Berenice's hair which is belated because it got tangled up in "space times world lines." But this probably is not true.

No one will lift a protest against the strictest analysis of Newton's work and his theories. If alive he would be the last one to claim that he did not make mistakes—in the light of present knowledge. He published a result too small by a half for the perigee motion of the moon (but it is said that he had the right result in his notes). He missed Fraunhofer's lines though just on the verge of their discovery. His law of attraction may need to have an added term as suggested. His corpuscular theory of light may need revision, but it may yet be found to be a near relative of the "modified corpuscular" theory, which is hinted at, or to Planck's "quanta energy" theory.

It cannot certainly be charged against Newton that he ever "tangled up space and time," that he ever "warped" space, that he ever called the surface of a cone a "plane," that he ever hitched the earth to space by a rope over a pulley. Newton believed that his apple fell farther toward the earth than the earth toward the apple, not as Einstein says the earth was "jerked" up to hit the apple.

Euclid's geometry may only be reserved for practical common sense purpose, and still allow very ingenious men to build up from assumed postulates, definitions and axioms perfectly consistent geometries and locate them wherever they please in space and still leave plenty of room for any other bright man to invent another. That is what space is for, a place to put things in and move them about in. Helmholtz, who will generally be acknowledged to be something of an expert in "Geometrical axioms," allows it likewise. He says, "Every new votary, coming with fresh zeal to geometry, naturally strives to succeed where all before him have failed. And it is quite right that each should make the trial afresh; for, as the question has hitherto stood, it is only by the fruitlessness of his efforts that he can be convinced. Meanwhile solitary inquirers are always from time to time appearing who become so deeply entangled in complicated trains of reasoning that they can no longer discover their mistakes and believe they have solved the problem. The axioms of parallels especially has called forth a great number of seeming demonstrations."

TIME AS A FOURTH DIMENSION

Much is made of time as a fourth dimension by fourth dimension adherents. In what is to follow we shall find an entire scheme based on what is called a "four dimension world," time being the fourth dimension.

In a proper sense it is no new thing to use *time* as a co-ordinate in constructing a curve which represents a quantity which varies with time.

A good illustration may be taken from Croll's "Climate and Time." Croll is defending the theory that the glacial period on the earth and

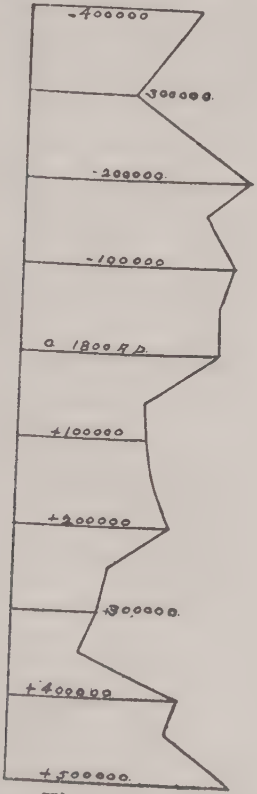

FIG. 1. Time as a co-ordinate

other great climatic changes were caused by changes in the eccentricity of the earth's orbit, on account of which change the comparative distance of the earth from the sun at perihelion and aphelion was so great as to cause great change of intensity of heat at those times. He computed from Leverrier's formulæ the eccentricity at intervals for a length of time running back three million years and forward one million years. Then he constructed a curve by taking two axes at right angles, laid off on the X axis spaces of (say) one inch for each time of five thousand years. At these points he erected perpendiculars each representing to scale the eccentricity of the orbit at that time, and joined the various points by a curve of eccentricity. To find the eccentricity at any intervening time, simply measure the ordinate and reduce it by the scale.

This will suffice to illustrate the use of time as a co-ordinate. It is not a fourth dimension, to take us out into an imaginary space, but simply used to shorten the work of computing values for the varying quantity at any time.

TIME AS A FACTOR OR MULTIPLIER

In most of the cases in which time is said to be a dimension, time is merely an abstract factor. The dimension is in fact a length which is found by multiplying the unit length, or length passed over in a second, by the number of seconds or by the time. Thus, in the Minkowski four-dimension scheme, one co-ordinate is called time co-ordinate, which is really the distance passed over in the time. That is, the co-ordinate is ct., in which c is the velocity of light or the distance passed over in a second multiplied by the number of seconds in it.

Engineers make much use of the graphical method of computation. They have no hesitancy in using a space time combination for fear they may reduce space and time to a "shadow" or find themselves off in hyper space, or imaginary space.

I have dwelt thus on the matter of time as a so-called dimension because so much of mystery has been made of its use as leading off into the space which some have a fancy to call imaginary, or a "four dimension world."

CHAPTER II

A RECENT INVENTION OF MUCH INTEREST

There comes in recent times a new scientific discovery, perchance invention, which has stirred unwonted interest or curiosity. Books about it have been published in many languages. It is the GENERAL RELATIVITY OF EINSTEIN.

It may seem strange that a theory which seems to be very close to a metaphysical theory should excite such popular curiosity. A large part of it, no doubt, comes from the outre and exaggerated statements about it and the uncanny things it is said to reveal.

A certain real interest is aroused by what it claims to have done that Newton could not do with Mercury and light, and the disquieting statement that we must learn our mechanics all over again.

If it does those alarming things claimed for it, distort our bodies, make our clocks unreliable, shorten our yard-sticks, we ought to study it to see if we can invent some counter irritant. If we must study our mechanics and astronomy all over again, the sooner we get at it the better. But if we can straighten out the kinks in our planets' orbits by a mere substituting in a small equation, as Einstein does, maybe our mechanics will be easy. Stockwell said that if he had followed his predecessors in their methods of finding the motion of the perihelion and nodes of the planets it would have taken an ordinary lifetime to write down the equations. Even with his revised methods it took pages to hold the equations he had to use. Hail! Einstein's simpler equations.

But better than all. If we can find in it a way to live forever, without dying to do it, we will wade through the pages of vector analysis which Einstein's disciples have set up to bar our way to his final simple equations. If we can lose our weight without fasting or too violent exercise, it may save railroad fare.

We really know, however, that these absurd things found here or there in sensational writings even Einstein's, do not legitimately belong to the theory.

Yet a glance through books that have been written from Slossen and Harlow at one end to Eddington, Cunningham and Einstein himself at the other, seems to discourage serious study. "In the history of science, the year 1919 is not likely to be known as the year of the overthrow of the German Empire, but as the year of the overthrow of Newton's law of gravitation." "Copernicus did not discover a new fact about the solar system, he only invented a lazier way of thinking about it." Slossen.

"In our conventional language we speak of the sun as exerting a force on the earth. This force, however, brings about a distortion or strain in world lines, or what amounts to the same thing, a distortion or strain of time and space."

"The earth moves in a curved orbit, not because the sun exerts a direct pull, but because the earth is trying to find the shortest way through a space and time which has been tangled up by an influence radiating from the sun." Eddington.

"At this point Newton's conception fails, for his views and his laws do not include strains in space. Newton's law must be supplemented by one which includes such distortions." Einstein.

Professor Russell says: "Asked one time to express the difference between his conception, and the law of gravitation in terms understandable to the layman, Dr. Einstein said: 'Please imagine the earth removed, and in its place suspended a box as big as a room, or a whole house, and a man inside floating in the center, there being no force whatever pulling him. Imagine further, this box being, by a rope or other contrivance, suddenly jerked to one side, which is scientifically termed accelerated motion. The person would then naturally reach bottom on the other side. The result would consequently be the same as if he obeyed Newton's law of gravitation, while in fact there is no gravitation exerted whatever, which proves that accelerated motion will in every case produce the same effects as gravitation. I have applied this new idea to every kind of accelerated motion and have thus developed mathematical formulas which I am convinced give more precise results than those based on Newton's theory."

It is scarcely an exaggeration to say that Einstein hitched the earth to space or the moon and jerked it up to hit Newton's apple. (Though he speaks of a stone falling.)

In deducing those "formulas which give more precise results than those based on Newton's theory," Einstein says in his letter to the London Times: "The way was harder than was expected, because it contradicted Euclidean geometry. In other words, the laws according to which material bodies are arranged in space do not exactly agree with the laws of space prescribed by the Euclidean geometry of solids. This is what is meant by 'a warp in space.' The fundamental concepts straight, plane, etc., accordingly lose their exact meaning in physics."

This discovery of Einstein's that "material bodies are actually arranged in space according to non-Euclidean geometry" will be quite a help to inventors of such geometries, for they never went farther than to say that if we had longer base lines for our astronomical measurements, and more perfect instruments, the departure from Euclidean space might be detected.

It is to be presumed that Einstein assumes that the verification of his prediction of the bending of light by gravity (or rather by warping of space) and solving the Mercury riddle, justifies his claim. To any who may be disposed to question his claim, he can say you are not one of the eleven. He is reported to have said that "not *twelve* men in the world can read and understand fully his book." This, probably, is a surer way to protect his device than even an international patent. Also it is a good way to thwart the critic. The eleven men who break in will not give it away, and those outside dare not criticise what they cannot read. Besides, *eleven* apostles is the standard, even another one might be dangerous.

Newton, fortunately, did not hedge his work about. Though his Principia is not easy reading, more than eleven men and women have read it, and saw that it meant something.

"Newton showed in the Principia how every known phenemenon of the motions, shapes and tides of the bodies of the solar system could be derived from it. *It became in the hands of his successors one of the most valuable means of discovery,* and if we are ever able to find out with certainty what has been the evolution of the solar system and what it will be in the future, we shall use the law of gravitation as an essential principle in the discussion." Professor Moulton.

"The grand truth of Newton's first law is shown in celestial motions. So irregular is the motion of the moon, when considered carefully, found to be, that no amount of the most exact observation alone (unaided by physical investigation) could enable us to predict its place even twenty-fours beforehand with anything like the accuracy with which it is predicted four years in advance in the Nautical Almanac." P. G. Tait.

It is to be hoped that Einstein did not make that boast, as it places him in too strong contrast to such a modest man as Newton, of whom Leibnitz, the brilliant German scholar, says: "Taking mathematics from the beginning of the world to the time when Newton lived, what he had done was much the better half." Of whom the great French mathematician, La Grange, says: "Newton was the greatest genius that ever existed and the most fortunate, for we cannot find more than once a system of the world to establish."

But Newton said of himself: "I do not know what I may appear to the world; but to myself I seem to have been only like a boy playing on the seashore and diverting myself in now and then finding a smoother pebble or a prettier shell than ordinary, whilst the great ocean of truth lay all undiscovered before me."

Sir Oliver Lodge's comment on relativity is rather discouraging. He has spent his life in research and experiment, mostly along the line of subjects related to relativity. He comments somewhat on relativity. He does not scold. He says: "I am not abusing the genius of Einstein and his brilliant disciples. I can but admire the skill with which they wield their ponderous instruments. They have a theory—most of them—that our physical theories, perhaps all theories, are founded on convenience rather than on our striving toward absolute truth. We may consider the sun as revolving about the earth or the earth about the sun." Then he says: "Earth does rotate on its axis, the hosts of heaven do not revolve around it once a day. The ether does exist or it does not." Of those who reason away the ether and still accept wave motion of light and electricity he says: "To attribute such a property of wave transmission to a mere abstract geometrical space with nothing in it and no specifiable properties is to stultify ourselves, especially if we hold to the wave theory, and to the probability of our ascertaining and stating the truth of reality, and not in our undoubted power of writing down convenient equations." We shall see later that Einstein calls *space æther.*

So many able men have accepted relativity at least on trial that Einstein may no doubt be warranted in being jubilant and disposed to be "cockey." If he has discovered a principle which has eluded wise men for six thousand years, he may be as happy as was Kepler.

Kepler after by almost infinite labor having proved what are called Kepler's three laws of planetary motion, in the preface to one of his books in most delirious mood writes: "Nothing can hold me; I will indulge in my sacred fury; I will triumph over mankind by the honest confession that I have stolen the golden vases of the Egyptians to build up a temple for my God, far away from the confines of Egypt. The book is written to be read, either now or by posterity

—I care not which; I may well wait a century for a reader, as God has waited six thousand years for an observer."

The true scientific spirit demands that we keep an open mind and try all things and hold fast what is true. We may excite as much laughter in future years as the "Stand patters" did in Galileo's time. Galileo wrote to Kepler: "Oh my dear Kepler how I wish we could have one laugh together! Here at Padua is the principal professor of philosophy whom I have repeatedly and urgently requested to look at the moons and planets which he persistently refuses to do. And the Professor of Pisa laboring before the Grand Duke as if by magical incantations to charm the new planets out of the sky." Sizzi, a townsman of Galileo, argued the satellites of Jupiter out of the sky. "The satellites are invisible to the naked eye and therefore can exercise no influence on the earth, and therefore would be useless and therefore do not exist."

"Besides as the Jews and other ancient nations, as well as modern Europeans, have adopted the division of the week into seven days and have named them from the seven planets: now, if we increase the number of planets, this whole system falls to the ground." Sounds somewhat, it is true, like the convenient as a substitute for reality, which Lodge criticised.

I shall not attempt an elaborate review. I shall study it as presented by some of the eleven and by Einstein himself. If I expose anywhere what seems to me to be a fallacy, or exaggeration, or absurdity, the chosen ones may choose to charge that I have not been "anointed." Besides, if it is merely a matter between the observer and the stars as to whether they revolve about the earth or the earth rotates, why is it not a matter between each person and relativity as to how much of it is worth while.

CHAPTER III

RELATIVITY

ITS ORIGIN AND ITS CLAIMS

Einstein says that "The theory of Relativity is like a house with two separate stories, the *Special* relativity theory and the *General* relativity."

He relegates Special relativity to the basement and reserves the parlor for General relativity. Though it seems to me that he uses the principal piece of furniture from the basement in this parlor.

I think it better to say Special relativity may be considered as having two rooms on one story and General relativity a different story, though we would naturally expect General relativity to include Special relativity, and be the whole house. We may then consider Special relativity to include what may be called Dynamical Relativity and Optical Relativity. Dynamical Relativity is stated thus by Cunningham—one of the eleven, no doubt. "It is impossible by means of any dynamical phenomena to ascertain *absolutely* the velocity of any material particle, but the *relative* velocity of any point with respect to any other is a uniquely determinable quantity."

A clear statement of the reason for failure to find what we can be sure is absolute motion by *dynamical* phenomena, is made by Thompson and Tait in their Natural Philosophy. "All motion that we are or can be acquainted with is relative merely." (This really covers more than dynamical motion.) "We can calculate from astronomical data for any instant, the direction in which and the velocity with which we are moving on account of the diurnal rotation. We may compound this with the similarly calculated velocity of the earth in its orbit. This resultant again we may compound (roughly) with the velocity of the sun relatively to the fixed stars. But even if all these elements were accurately known, it could not be said that we had attained any idea of an absolute velocity, for it is only the sun's relative motion among the stars that we can observe. And in all probability sun and stars are moving (possibly with very great rapidity) relatively to the other bodies in space."

Cunningham again states what we call the Optical Relativity thus: "It consists in the general hypothesis, based on a certain amount of experimental evidence, that the problem of determining in a physical sense the absolute velocity of a body is one that can no more be solved uniquely by the help of *optical* and electrical phenomena than it could by means of dynamical observations." The following is the experimental evidence. When the sun and stars will not stand still for their purpose, they tried the æther. If it is immobile it may furnish the very medium in which a frame of reference may be set up to which absolute motion may be referred. The method employed was aimed at proving that the æther is immobile with reference to the earth. That is, that the æther does not in any way move with the earth's motion. We are not convinced in advance that even if we can succeed in showing that the earth's motion with reference to the æther is so far absolute that we have gotten near to a general absolute motion. 1st, The æther may not be immobile with reference to other bodies in the universe. 2nd, How can a frame of any practical value be fixed in a homogeneous knotless medium? Where is the origin? If for us we find it at any instant, we will never be at that origin again. If we point our frame of reference in a given direction with reference to the earth's motion, how will we identify it again for our use? Any way, better find the fact before we explain how to use it.

The proofs of such motion, if possible at all, must be made by optical or electrical experiments, as these are the only agencies to which the æther responds.

Of the various experiments which were tried, the crucial one was the now famous experiment made by Michelson and Morley. In fact, almost the entire fabric even of General Relativity is woven about the attempt to account for the failure of that experiment to show what it was expected to show. Though they generally feign gratified surprise when it emerges from their adapted equations.

It is important, at the outstart, to explain this experiment, otherwise we shall be in the dark as to the real meaning of the formula which is constantly used in relativity. My explanation shall be brief and schematic.

APPARATUS

Michelson and Morley fixed two equal rods at right angles to each other and fastened at the end of each rod a mirror at right angles to the rod and a divided mirror at the junction of the two rods. They mounted this apparatus on a stone block floating in mercury so that it could be readily turned about, without jar, in any direction. They then turned the apparatus so that one arm pointed in the direction in which the earth was moving at the time and, of course, the other arm was at right angles to the direction of the earth's motion.

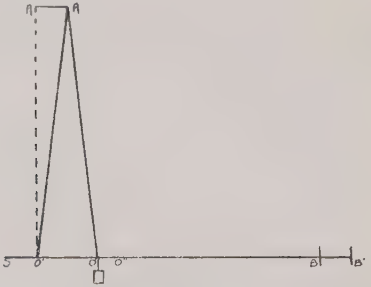

FIG. 2. The Michelson-Morley experiment

Thus let O A and O B represent the two arms of the apparatus, each carrying a mirror at its end, and a divided mirror being fixed at O.

ASSUMPTIONS

1. If light is sent out from O, it will travel in the æther with a velocity which is independent of the motion of its source or of the motion of the mirrors.

2. If the æther is immobile and the earth moving through it, it will take light sent out

from O longer to overtake the mirror at B and return, than it will to travel to the mirror at A and return.

3. If the light sent out from O in the two directions, comes back to their interferometer with the difference of time which is computed on the theory that the æther is immobile and the earth moving through it, then the immobility of the æther with respect to the earth is proved.

EXPERIMENT

Light is sent from S toward the half mirror at O. It is divided at O, one part passing through a half of the mirror on toward B, along the line pointing in the direction in which the earth is moving. A part is reflected by the half mirror at O at right angles to O B toward the mirror A. The rays are reflected from the mirrors and returned. The central mirror O has moved during the time of the rays going and returning. By the theory upon which the experiment is made, the light from the mirror A ought to reach the central mirror at a point O′ to which it has moved in the interval; and the light from B, a little later, ought to reach O″ a point a little farther along than O′. The ray from each was reflected then to the interferometer at D. The displacement of the interference fringes in the interferometer is expected to show the difference between the two arrivals. By the theory, as shown in the computation below, the difference ought to have been $\frac{v^2}{c^3}d$, in which v is the velocity of the earth at that point, c is the velocity of light and d is the length of an arm. The result given in seconds. To their surprise the reflected rays returned at the same time, showing that O′ and O″ coincided. And the experiment, so far, showed nothing.

COMPUTATION OF THE DIFFERENCE IN TIME OF RETURN ACCORDING TO THEORY

1. While the light is travelling to reach mirror A, the mirror has moved vt. Therefore light will have to travel O A′ to reach the mirror.

Hence $t = \frac{\sqrt{v^2t^2 + d^2}}{c}$ or $c^2t^2 = v^2t^2 + d^2$.

Therefore $t = \frac{d}{\sqrt{c^2 - v^2}.}$ It will take equal time to return along A′ O′ $\therefore 2t = \frac{2d}{\sqrt{c^2 - v^2}.}$

2. The light which is pursuing mirror B is gaining on it at rate of c—v. And the time necessary to overtake B is t, $= \frac{d}{c - v}$. Coming back to meet the central mirror, the light and mirror

are coming on to meet each other with joint velocity $c + v$. Therefore, the time of retracing its course is $t_2 = \frac{d}{c + v}$.

Therefore the entire time of going and returning is $t_1 + t_2 = \frac{d}{c + v} + \frac{d}{c - v} = t' = \frac{2dc}{c^2 - v^2}$.

Therefore the difference of time of return from A and B (is

$$t - t' = 2d \left(\frac{c}{c^2 - v^2} - \frac{1}{(c^2 - v^2)^{\frac{1}{2}}} \right) =$$

$$2d \left(\frac{c - (c^2 - v^2)^{\frac{1}{2}}}{c^2 - v^2} \doteq \frac{2dv^2}{2(c^3 - cv^2)} \right) =$$

$\frac{v^2}{c^3} d$ approximately).

As was before said, no appreciable difference of time was found, though they could have detected a much smaller difference than the theoretical difference. The result seemed to thwart the effort to get an immobile frame of reference in the æther. But Lorentz and others are not satisfied that the result proves that the æther is not immobile. They are almost sorry that the experiment was ever tried, for it introduces another result for them to explain. But they bravely attempt to explain it.

1. Might not the arms of the apparatus have been enough unequal to account for the negative result? The difference in length necessary to

veil the difference in time is so small that it takes great care in measurement. This objection was answered in the experiment. The apparatus floating in mercury could be easily turned through any angle. They turned it so that the two arms exchanged places. The result was the same—no difference of time in the return of the two rays. Indeed the result was the same no matter at what angle the apparatus was placed with reference to the earth's motion, even if one arm pointed in the opposite direction to that of the earth's motion.

2. The Fitzgerald-Lorentz contraction theory.

Fitzgerald first, and Lorentz later, invented the theory that the two arms automatically adjusted their lengths so as to just compensate for the computed difference of times and veil it. According to Lorentz' theory the arm that pointed in the direction in which the earth is moving, automatically shortened itself so that the time it took light to go and return on it was just equal to the time it took light to go and return in the right angle line. Lorentz' theory is based on the assumption that all material bodies are made of electrons, that these electrons are spherical when at rest, but when they are moving they become oblate spheroids with the minor axes pointing in the line of motion. So when the Michelson-Morely apparatus was moving in the direction of the earth's motion, all the electrons became oblate spheroids with minor axes in the line of motion and major axes at right angles to that motion, and that shortened the arm pointing with the earth's motion just enough to compensate for the motion of the mirror.

WHAT MUST BE THE RATIO OF THE SEMI-MINOR AXIS OF THE ELLIPSE TO THE SEMI-MAJOR AXIS which generates the oblate spheroid, or how much shorter must be the line in the direction of motion than the right angle line? Let d be the length of the right angle line, and d′ the length of the line pointed in the direction of motion. We have already found expressions for the times of going and returning in those lines according to the Lorentz theory. Now these two times must be equal according to the theory. Therefore

$$(1)\ \frac{c\,d'}{c^2 - v^2} = \frac{d}{(c^2 - v^2)^{1/2}}\quad (2)\ \therefore d' =$$

$$d\frac{c\,(c^2 - v^2)^{1/2}}{c^2 - v^2} = d\,(c^2 - v^2)^{1/2} = d\left(1 - \frac{v^2}{c^2}\right)^{1/2}$$

$$= d\left(1 - \frac{v^2}{2c^2}\right)$$

approximately, or the right angle line is shortened $\frac{v^2}{2c^2}$ approximately, when pointed in direction of motion. This formula for d′ is the very basis of Relativity. Ignore it or disprove it and the entire "ponderous array of equations" involving it falls to the ground.

He would be a daring man who would challenge the infallibility of this formula which enters so much into the fabric of relativity. It is accepted by so many wise men. But we cannot refrain from a wonder at the confidence with which it is accepted on such slight proof or no proof.

Eddington says, "The plain meaning of the experiment is that both arms have a length *a* when placed along the right angle line and contract automatically to a length $a\sqrt{1 - \frac{v^2}{c^2}}$ when placed in the line of motion of the earth. By experimenting at different times in the year with different orientations the existence of the contraction has been *fully demonstrated.*"

The only thing wrong with this statement is that it is not true. These experiments did not prove anything about material contracting. It simply proved that the experimenters were wrong about their assumption that it makes any difference as to the orientations of their apparatus, on the time of travel and return of light. The facts are like this: These experiments prove:

1. It takes light just as long to go and return along all lines of equal length on the earth. 2. This fact negatives what they were attempting to prove. 3. Lorentz asserts that these experimenters did not do what they said they did, that is, they did not send light along *equal* lines. If they had sent the light along equal lengths they would have found that the times of light going and returning along differently directed lines would have been as they predicted. That they were fooled owing to their being ignorant of the fact that the arm of their apparatus which pointed in the direction of the earth's motion automatically shortened itself just enough to deceive them. If they had known that and made that arm just enough longer than the other to offset the contraction, all would have been well.

4. Lorentz computed the amount by which they were fooled in the length of the arm which pointed with the earth's motion, and hence deduced the famous Lorentz *Contraction Coefficient.*

5. Special relativitists profess to prize most highly the Michelson-Morley experiment, while in fact they have thrown it entirely away. They do not accept its results. Scientific men generally accept the result of properly devised and executed experiment. Why make any experiment

if, when it fails, we doctor the result so as to make it appear that it succeeds by substituting for the result some occult cause for failure, a cause which no one can test.

6. Lorentz' theory and his contraction formula is not a theory of motion of light, but a theory of the construction of material bodies; that they are made of electrons and these electrons change shape when in motion. He applies it to showing how these experimenters proved what they failed to prove.

7. Lorentz' theory is based on the assumptions concerning the electrons that have not and probably cannot be proved. No one has proved that an electron changes its shape when in motion. That it does change shape is an assumption based on another assumption as to the change of mass when in motion. That it does change shape is most probable, but not necessarily; in fact, not conceivably as Lorentz assumes. We shall take that subject up later.

It does seem strange that those who accept and use the Lorentz contraction formula do not see that they are assuming as proved what they keep constantly affirming that has not and cannot be proved. Thus Carmichael says: "Both on the optical and electrical side the attempt to detect the motion of the earth through the æther fails: no experiment is known by which it can be put in evidence." Yet he adopts the Lorentz coefficient. Those who adopt that coefficient assert that this experiment did prove that the æther is immobile with reference to the earth when you apply this contraction to their apparatus.

CHAPTER IV

DEFECTS IN THE MICHELSON-MORLEY EXPERIMENT

The Michelson-Morley experiment fails to be of any value, however, in these important particulars.

1. It did not give any evidence as to whether the Lorentz contraction, if there is such contraction, applies to the earth as well as to their apparatus. In order to test that question it would be necessary to do what is probably impossible. Instead of confining their experiment to an apparatus a few feet long composed of rods fastened together, they should have had their mirrors miles away so that the light would have to travel over a contracted earth. The impossibility of it is due to two causes, the impossibility of making accurate enough measurements along the right angle line and the direct line; also, the impossibility of reversing and interchanging the two arms. Yet in the clock and distance discussion as we shall see, it is assumed that the earth con-

tracts. Eddington sees that, it seems, and we begin to hope something from his conversion, but he soon backslides.

He says: "The Michelson-Morley experiment is necessarily confined to solids of laboratory dimensions in which internal gravitation has no appreciable influence. There is, therefore, *no experimental proof that a body such as the earth, whose figure is determined mainly by gravitation, will undergo the theoretical contraction owing to motion.*" If that is true it knocks the props from under a large part of the clock wrecking in which his disciples indulge, for they all assume that the earth between the stations where the clocks are, contract according to the Lorentz formula, or the Einstein Relativity.

But Eddington as usual is elusive. He has found that Lorentz was right about the contraction of two rods fastened to a stone, for they were too little for gravity to fool with, but that Lorentz was wrong about his theory contracting as big a thing as the earth. Then again Lorentz was very short sighted and provincial in confining his contraction to material or even electrons when all space lay open to him. Eddington will apply a variety of contraction coefficient, one to suit every corner of the stellar universe. He says: "We have learnt one important thing. Our space is not absolute: it is determined by our motion." (Where did we learn it.) "If we transfer ourselves to the star Arcturus, which is moving relatively to us with a speed of more than three hundred km. per second, our space will not suit it, since it was designed to eliminate our own contraction effect. The contraction rates $1 - \frac{v^2}{c^2}$ must be different for Arcturus: and the space surveyed with a material yard measure carried on Arcturus will differ slightly from the space surveyed with the same yard measure on the earth." It is all very wonderful. The earth is too big to contract, but the space around the earth is contracted and has to be measured by a specially contracted yard measure. Arcturus must certainly be too big to contract, for he is many million times as big as the earth, but the space around him is contracted and space and time are tangled up so that a special yard stick is needed to measure a yard.

2. A second defect in the Michelson-Morley experiment was in the fact that no means was devised to find out whether light arrived at the two mirrors at the end of the rods at the same time. In all the time comparing and space comparing in relativity, it is assumed that light does

not reach the mirrors at the same time. No part of the experiment tested that point, and the fact that light returned at the same time makes it probable that it did reach them at the same time. If not, where did they catch up?

3. A third cause of uncertainty is due to the fact that light from a terrestrial source was used instead of sunlight, or light from a non-terrestrial source.

This criticism will seem entirely irrelevant to the proponents of relativity. Einstein says: "The second principle on which the special relativity rests is that of the constancy of the velocity of light in a vacuum. Light in a vacuum has a definite and constant velocity, independent of its source." See later how he hedges.

Carmichael says: "A principle which has long been familiar in the theory of light is that the velocity of light is unaffected by the velocity of its source. It is stated in the postulate in relativity, 'The velocity of light in free space is independent of the unaccelerated velocity of the source of light.' "

It is a "postulate," but is it true that the velocity of light is independent of the motion of its source? Possibly these experiments are the first tests of its truth for light originating on the earth.

It is ignorant and heterodox to doubt its truth, but heterodox theories of light are being groomed for orthodoxy.

The discussion of the nature of light and its method of transmission through space has filled volumes of speculative and patience trying mathematics. By corpuscles, by undulations, by "wrinkles in space," it has come according to the fancy or research of the author. It has been sent to us through æther rigid, æther elastic, and just æther and no æther. It may be allowable to make a new try, especially if we have the very best company, who seem to be ready to go, at least a part of the way.

Drude, in his Theory of Optics, says: "The motion of the earth can never have an influence of the first order in v upon the phenomena of light which are produced with terrestrial sources, for the periods emitted by such sources are merely the relative periods. On the other hand when celestial sources of light are used the effect of the earth's motion can be detected, for, in this case, the relative period depends upon that motion."

It may be that this quotation is not quite susceptible of the interpretation I have given, but it seems to warrant it.

Cunningham, in his Theory of Relativity, says:

"As a matter of fact, the trend of thought among certain physicists at the present time is rather toward the assertion that the classical conception of the æther is insufficient to comprehend certain new experimental facts that have emerged, especially in the matter of radiation, photo electric effects, and specific heat. There is a tendency to think of radiation as having a more definite individuality than that of a mere disturbance in a continuous medium. The theory of *energy-quanta* is inconsistent with the usual view put forward as to the nature of radiation, and is suggestive of a modified *emission theory of light*."

This *energy-quanta* theory is epitomized by Comstock and Toland in their "Nature of Matter and Electricity."

"Atoms of matter do not radiate energy continuously, but in certain definite units. Energy from the sun is considered to be in the form of separate units, 'Bullets of energy,' we may say."

"This means that light and heat from the sun fall on the earth like a shower of rain. It is as if in Planck's theory the electron emitted 'bullets of radiation.' In the minds of those most competent to judge it has passed from a possibility to a probability." Whether these quotations entirely warrant the construction that they open the way to a theory of velocity of light modified by its source, since they do not directly assert it, they show that old theories of light are not sacred.

One more eminent mathematician may be quoted who is more specific. Poincaré in his "Value of Science" suggests that velocity of light may not be invariable, though he would attribute it to a change in the æther due to the motion.

"Instead of supposing that bodies must undergo a contraction in the sense of motion and that this contraction is the same whatever the nature of the bodies and the forces to which they are otherwise subjected, could we not make a more simple hypothesis? We might imagine that it is the æther which is modified when it is in relative motion in reference to the material mediums which penetrate it, that when it is thus modified it no *longer transmits perturbations with the same velocity* in all directions. It might transmit more rapidly those propagations parallel to the motion of the medium and less rapidly those propagated at right angles. The wave surface would then no longer be spheres, but ellipsoids, and we could dispense with that extraordinary contraction of the bodies."

CHAPTER V

DOES A TERRESTRIAL SOURCE OF LIGHT GIVE ITS MOTION TO ITS LIGHT?

It is an ignorant thing to try to pull away the foundation upon which the entire structure of, at least, special relativity is built. If these "modified corpuscles," "ellipsoidal æther waves," "bullets of energy," any or all of them, deceived Michelson and Morley by modifying the velocity of terrestrial light in a way to simulate the bullet from a moving gun, it kills the Lorentz contraction formula, and when it falls, one story of Einstein's house is badly wrecked, and it is doubtful that the other story may be saved.

Let us see, then, if radiation simulates "bullets" of lead, what effect it would have on the Lorentz contraction.

BULLETS FIRED FROM MOVING GUNS

Let a gun be mounted at A and be moving toward B with velocity V. Let the distance A B

=C. Suppose the velocity which the powder can give to the ball = C.

Suppose another gun to be mounted at B, pointed back to A and moving also with velocity V in the same direction in which A is moving. The ball in the gun A is moving with the gun at a speed of V. Let the ball be fired from A toward B. The powder gives it a speed C and it already has a speed V, hence it moves now with speed C + V. While the ball is overtaking B, B has moved a distance V to B′; therefore, the whole distance the ball has to go to overtake B is C + V. Therefore the ball reaches B′ in one second.

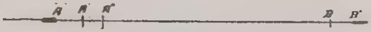

FIG. 3. Bullets of lead for bullets of light

At the instant the ball reaches B′, let the gun at B′ fire a ball back toward A. The ball in the gun was moving forward with the gun at a speed of V. The speed V must be subtracted from the speed C which the powder gives to the ball, hence the ball goes back toward A with a speed C — V.

While the first ball was reaching B′, the gun at A has moved a distance V to A′, and while the second ball is coming back it will move a distance A′A″ equal to V, and the distance B′A″

= C — V. Therefore the second ball will have to travel a distance C —V, with a speed of C — V and will reach A″ in one second. The time elapsing from the firing the first gun until the second ball comes back is two seconds, which is just the same as if the guns had stood still. This is the same result that Michelson and Morley got in their light firing.

LIGHT MOVING AS A BULLET OF ENERGY

Suppose light from a terrestrial source be radiated as if it were "modified corpuscular," or acting as coming from "bullets of energy," the same conditions may obtain.

The "corpuscle" or "bullet" has a speed V with its source, acquires a speed C from radiation or vibration or emission, and so moves with speed C + V and reaches the mirror in a second.

What happens when light strikes the mirror?

Reflection of light is thus explained by Comstock and Toland: "When the electrons within a body are set in vibration by an impinging light, they will act as radiators of a new light, and if the body has a flat surface those emitted from the electrons near the surface will join to form a definite wave which travels back in the opposite direction." Therefore when the light strikes the mirror B, the electrons radiate back with speed C — V and as the original source has moved 2V by the time it takes light to get to it again, the distance light has to travel is C — V and therefore it takes it one second to retrace and two seconds for the going and returning. Just as it would have taken two seconds if the apparatus had been at rest. If some such state of affairs should be found true, relativity will have a hard time of it.

However, in discussing relativity it is only fair to allow its postulates unless they are definitely disproved. I shall still further discuss light in connection with Einstein's deflection of light.

SPECIAL RELATIVITY

Appointing a Guardian

In developing the theories and results of relativity its exponents introduce a fiction which is useless except that it accomplishes its possible object of rendering it a little more confusing to any but the eleven. The fiction consists in two systems S and S′ and sometimes a third S″. If there are three, one of them stands still and the other two move parallel to each other. Various things are taking place on one of these systems, such as comparing clocks, measuring with yard sticks and such like. The occupant of this system is a simple fellow; he does not know that he is moving and does not know the fatal effects of it. On the other system is a wise and beneficent man. He constitutes himself a guardian of the simple one on the other system, to see that he does not fool himself about his clocks, the length of his body and the size of his farm.

It would be easy enough until we find that the guardian is on a moving system and he is just as much fooled as is his ward on the other system. Then a guardian for him is appointed on the first system. Often we are in doubt about which guardian is talking, then they seem sometimes to be both talking at once.

Certainly it seems just as efficacious to have both the wise guardian and the simple ward on the same moving system. The proof of that fact is that Einstein and his disciples are on the moving system, the earth and they have found out what is happening to their wards on the same moving system without stepping off onto another moving platform. But we shall in general let them use their own method.

CHAPTER VI

SOME STARTLING THINGS THAT RELATIVITY DOES

I. Relativity Discredits Our Clocks.

"There is no way of telling by light signals whether two clocks at a distance are keeping the same time."

This stirs the popular mind with something of alarm. Is this new relativity to wreck our confidence in our clocks and watches? If this is a new freak of nature which affects clocks and watches, who will be safe on a railroad train? Every new engineer who mounts the cab will put the throttle of his engine in the hand of death. To assure ourselves we may turn to a sane author, though stilted and involved.

"Einstein's conclusion is that if light were the only means of communication between distant points by means of which a standard of simultaneity of events at different places could be set up, there would be the same arbitrariness in the measure of time and space that is suggested by the Lorentz transformation."

It might be well to remark for the information of Einstein and Cunningham that light never is used in the sense in which they are using it as a means of regulating clocks. Observatories regulate their clocks by the light of stars at meridian transit, but that is not what relativity means.

We get along fairly well with a slower method than light, that is by telegraph or electric current. A little group of astronomers were gathered around the indicator in the telegraph office at Norfolk, Virginia, the day before the total eclipse. They were listening to the beat of the pendulum of the clock in the Naval Observatory at Washington, D. C. They were setting their watches in the belief that they would do to use in reporting the results of the eclipse. They were content if they agreed within one or two seconds.

It is worth while to state how we do standardize even the best clocks. In the United States, the chief source of standard time is the Naval Observatory at Washington, D. C. There are three high grade clocks keeping standard time at this observatory. At night their errors are found from star observations, and after applying the corrections for them, the mean of the three clocks is taken as giving the true standard time for the succeeding twenty-four hours.

"At five minutes before noon, Eastern time, the Western Union Telegraph Company suspends ordinary business and throws its lines into electrical connection with the standard clock at the Naval Observatory. The connection is arranged so that the sounding key makes a stroke every second during the five minutes until noon, except the twenty-ninth of each minute, the last five seconds of each of the four minutes and the last ten seconds of the fifth minute. This gives many opportunities for finding the error of a clock at any point. Clocks are made which are automatically regulated by these signals. These time signals are sent out with an error usually less than *two-tenths of a second,* but it is frequently increased when a system of relays must be used for long distances." It is seen that our observatories get along without light signals—using electric currents, and they are content with an error of *two-tenths of a second.*

Let us see what frightful error we will commit when we try to set two clocks which are distant from each other to the same time. Einstein says "that if light is the only means of communication between distant points, there is the same arbitrariness in the measure of time as is suggested by the *Lorentz transformation.*"

I shall follow the general method given by Relativity.

Let two observers, A and B, be desirous of setting their clocks to the same time. By measurement let the point C be fixed midway between A and B. This measurement must be made with most scientific accuracy, as the times are to be set with greatest precision. It should be measured with compensation rods such as are used in measuring the base line for a meridian survey in finding the shape and size of the earth. It could not be done partly by triangulation, as all apparatus must be kept strictly in one line, since for every diverging line a different contraction will take place. If the distance between the points is great, it may take months, even years, as it took to measure certain base lines for meridian measures.

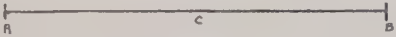

FIG. 4. Rating clocks by light signals

Suppose all this settled and C at exactly X distance from each station. We suppose that A and B are directly in the line of the earth's motion, the motion being toward the right in the figure.

1. The distances C A and C B while being equal are not X real feet in length, for they are measured with a contracted chain or rods, and though found to be X chains long each is only $\times \sqrt{1 - \frac{V^2}{C^2}}$ real chains in length.

2. The operator at C has arranged with each observer that he is to set his clock at (say) twelve when he sees the flash. The operator sends out his flash of light and it travels out both ways with velocity C (according to theory).

3. Let T be the time it takes the flash to reach A. Now the joint velocity with which it approaches A is C + V and the time T =

$$\frac{\times\sqrt{1-\frac{v^2}{c^2}}}{c+v}$$

4. Let T′ be the time it takes the flash to overtake B which is moving away from it with velocity V. The light is gaining on B with velocity C — V. Therefore $T' = \frac{\times\sqrt{1-\frac{v^2}{v^2}}}{c-v}$. It is evident that T and T′ are not equal and if each observer sets his clock at twelve when he sees the flash, the times will not agree.

5. Take the difference between the two times and we find it to be $\frac{2 \times v}{c^2\sqrt{1-\frac{v^2}{c^2}}}$.

It may be of interest to see how great is that difference in the times for stations at certain distances apart.

1st. Difference for two stations one hundred eighty-six miles apart. Call the velocities of the earth and light in round numbers 18.6 miles and 186,000 miles per second.

The radical would be very small and neglect it.

$$\text{The difference in times} = \frac{18.6 \times 186}{186 \times 186 \times 10^6} = \frac{1}{10^7}$$

seconds or one ten-millionth of a second. For a distance apart of 1860 miles the difference in the clocks is one-millionth of a second.

Not every common man can set his clock to nearer than a millionth of a second. When he finds the true state of the case, Einstein will have little terror for him.

2nd. The man in the moon sets his clock.

Suppose (a silly proposition, it is true) that the "man in the moon" and a man on the earth want to set their clocks at the same time. A point is chosen midway between the earth and the moon, at a distance of 120,000 miles from each. The operator will have difficulty in staying still, as he is not at the neutral point between the earth's and moon's attraction. But he may anchor on one of Einstein's "world lines" or get in one of Einstein's "warps in space." Suppose a time chosen when earth and moon are both moving forward with velocity 18.6 miles per second. The flashes are sent out and the man in the moon and the man in the earth set their clocks at twelve. They differ by $\frac{240{,}000 \times 18.6}{186 \times 186 \times 10^6} = \frac{1}{8000}$ second.

We wonder if Einstein and his disciples ever applied their theory to find the actual difference in time between two clocks set by light measurements. If they had, and found that for distances as far apart as across the continent of Europe the difference would be a quarter of a million times less than our best observatory clocks can show, would they stultify themselves by talking of clocks? Would they not confine their speculation and their arithmetic to the general effect of motion on *simultaneity?* We do not know much about "simultaneity," we do know about clocks. We must hasten to say that we do not discourage invention because it is at present useless; we are only pleading for honesty in telling what it is for.

II. A Device by Which a Man Would Never Grow Old.

No wonder that this catches the public fancy. If relativity points the way to the elixir of life everybody will want it. Cohn is said to illustrate the manner of not growing old in this way: "If, with the naked eye or telescope, you watch a clock; as you move away from it you will find that the minute hand takes a longer time to cover five minutes than the chronometer in your hand does. If you move away with the velocity of light, the clock hand would always seem to stand still." Of course there is nothing strange about the fact that the light from the minute hand in its other positions does not overtake you if you are running away as fast as light travels in pursuit. The only wonder is the marvelous eyesight.

The inference he makes is that he never grows any older because he doesn't see the clock hands go around. If he rates his life by the clock hands instead of by his chronometer or his pulse beats, a much easier way, less straining on the eyes, and more comfortable than the cold out among the stars would be to stay in a comfortable room, set the clock up on the mantel, stop its hands, keep looking at it and live forever. Eddington has a slightly different elixir of life. He dispenses with the clock and telescope. He says: "If a man wishes to achieve immortality and eternal youth, all he has to do is to cruise about space with the velocity of light. He will return to the earth after what seems to him an instant to find many centuries passed away." It almost discredits one's intelligence to discuss it, but the pleasantry of these humorists appears in the writing of so many bright writers that many people with a dull sense of humor think they are in earnest.

Everyone who travels around the earth travelling toward the west "loses" a day. The number of times the sun crosses his meridian is one less than if he had staid at home. His heart beats are just as many as if he had staid at home; his watch hands have gone around as many times as has the hands of his clock at home.

A much easier way for a man to live forever, or while the earth rotates, is, if he is at the equator, to start west when the sun is in his meridian, and travel at the rate of a little more than a thousand miles an hour. The sun would constantly be in his meridian and rated by sunrise and sunset he would never be "a day older." That is not a new relativity, it is just old-fashioned common sense to laugh at the absurd conclusion drawn from such well known facts.

III. Relativity May Wreck Our Bodies—Or Lorentz May.

If our bodies are changing violently in length as we turn from pointing in the direction of the earth's motion to a position at right angles, we ought to know it and take measures to conserve our health. To discover or invent a serum seems hopeless. The only two safeguards seem mechanical. First, we might sleep in an erect position—feet down. Second, with great ingenuity a bed must be made, mounted on cunningly wrought devices, which automatically turns so as to keep the occupant always pointing at right angles to the earth's motion.

That there is real cause for alarm is clear. Pictures are given showing an ordinary man when he is as he ought to be or as he is probably when pointing at forty-five degrees from the direction of the earth's motion the same man sawed off six inches or so when he points with the earth's motion, and then the same man six inches taller than normal when at right angles to the motion.

A recent author represents the victim as objecting to being violently dealt with and expressing doubt that he has been mistreated. He says: "It is ridiculous. If I am shorter in one direction than another I would know it." He is silenced by the usual knock-down, "You would if some things were shortened and others not. Besides, your eyeball is flattened so that you cannot tell that you are shorter."

If we are to provide a remedy, it is necessary that we compute the amount by which a six foot man is shortened. We have found that Lorentz makes him contract by an amount $\frac{v^2}{2c^2}\,l$. In which $V = 18.6$ miles, $C = 186{,}000$ miles, and L is the length of the normal body. Therefore the contraction of a six foot man $= \frac{(18.6)^2}{(186{,}000)^2} \times 6 \times 12$ inches $= \frac{1}{3{,}000{,}000}$ of an inch. That is, one-millionth of an inch.

In a recent article in Science, the thickness of the fur hair of different animals is given. A hair of the domestic cat for instance, is given as about one ten-thousandth of an inch thick. Comparing the thickness of the hair of the cat with the amount by which a six foot man is contracted by the Lorentz coefficient we find that he is contracted about one three-hundredth of a cat's hair or one-hundredth of one of his own hairs. These bald headed men who throw a wisp of their hair up over the top of the head are grossly overdoing it if they are doing it to compensate for the Lorentz contraction. In fact one hair would be a hundred times too thick.

IV. Our Yard-Stick Plays Us False.

In a recent lecture by a professor of astronomy, the usual indictment of the yard-stick is thus stated: "According to the principle of relativity, the answer to the question whether two material rods laid on the table at right angles to one another are of the same length or of different lengths depends on whether we *choose to think* that we and the room in which the apparatus is situated, are at rest in space or are moving in different directions with high uniform speed."

"Choose to think that we are moving with high speed."

This sounds quite Einsteinian. Eddington says: "The trouble is that we have inherited a preconceived idea of the way in which measures, if true, ought to fit. But the relativity standpoint is that we do not know and do not care whether the measures under discussion are true or not." One wonders and stands aghast at the wreckage which might come if various persons should choose to think that the room and apparatus are moving in all kinds of directions with all kinds of velocity.

That "choose to think" may be a slip of the pen.

But to return to the quotation. "The fact that when the two rods are laid side by side they are obviously exactly equal does not prove they are of the same length when we turn them so that they make an angle with one another."

On the strength of such statement the store keeper might undertake to measure his cloth always in the direction of the earth's motion. Books on astronomy and geodesy are bought. Men skilled in the knowledge of the earth's motion are employed, just as the chemist by the steel manufacturer. But alas! his cloth contracts too when turned in the direction of the earth's motion.

Maybe this astronomer would honestly tell him that his yard-stick would contract one-hundredth of the thickness of a cat's hair, and if the cloth did not change and the yard-stick did, when he had measured two million yards of cloth he would gain an inch.

It is a little provoking that not alone sensational writers, whom we could disregard, but men of learning and who seem to speak with authority, speak of our bodies, yard-sticks and clocks as if they had found something seriously affecting them. This protest in no way utters a word against the exceedingly fascinating pastime of assuming postulates and theories, writing down equations and manipulating them, and finally translating the result into fancies—even absurdities. Every mathematician does it just for the joy of it, and we chide him not any more than we say them nay when the lambkins skip upon the hillside for very joy.

Neither do we find fault because small things are discussed. There is much discussion of wave lengths of light. The mean length of the visible wave length is $\frac{1}{50,000}$ of an inch. True this is twenty times as long as the amount by which a man six feet tall is contracted by the Einstein coefficient when he turns from right angles to the earth's motion to pointing with that motion.

We are merely asking for honesty.

CHAPTER VII

EINSTEIN'S KINEMATICS.

We must adopt Einstein's kinematics or we are *lost*. Cunningham says: "There is a close relationship between the conception of objectivity of phenomena and the *principle* of *relativity*. We have been accustomed to associate *objective existence* in space with Euclidean geometry and Newtonian kinematics. But if we adopt the principle of relativity, objective existence is inseparable from what we have called Einstein kinematics. We may not conceive of a body as having physical reality unless the velocities of a given point as seen by two observers are related to one another and to the relative velocity of the observers by the Einstein addition formulæ."

We dare not hesitate, we must accept his formulæ. If we do not, there is no physical reality, and we shall lose our farms, our houses, our friends, our enemies, and finally ourselves.

EINSTEIN'S TRANSFORMATION FORMULÆ

Suppose we have a fixed body such as the earth may be assumed to be. We fix a point O on this body from which, as origin, we propose to measure distances. From O we draw a straight line OX with reference to which these points are to be described. On this fixed body is an observer who knows everything about distances and time on *his* system, and also about what is going on in the system to be now explained. On this line OX, is a point P at a distance X from O. This

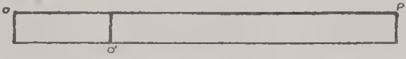

Fig. 5. Einstein's kinematics

distance is all right, for the wise man on the fixed body measured it. He knows that his steel chains are all right, his clock keeps good time, the solid earth does not curl up under him. Now another man makes a long narrow platform, long enough to reach from O out beyond P. He places this platform along beside OX. He marks a point on that platform and calls it O′. He says: "I propose to measure distance along my platform starting from O′, and will call the distance from O′ to P (for instance) X′." He starts his platform in uniform motion at rate v toward p. The man on the fixed body watches the other for a time t. He notes the o′ is now at a distance vt from o. They agree then to compare the distance from o′ to p as measured in the measures of the two men so as to compare the measuring units. The man on the platform calls his distance from $p = x'$. The other man says "you cannot take x' real feet and compare it with my length, for your platform has shortened since you are moving. You must use x' divided by the Lorentz contraction. $\therefore x'\left(1 - \frac{v^2}{c^2}\right)^{-\frac{1}{2}} = x - vt$. (A)

They now want to compare their units of time to see if they disagree likewise. They start again with the origins o and o′ together. The velocity of a beam of light is chosen as the best unit of measurement. A beam of light is sent out from p just when o and o′ agree. The light will have to travel for a time $t = \frac{x}{c}$ to reach o, and for a time $t' = \frac{x - vt}{c}\left(1 - \frac{v^2}{c^2}\right)^{-\frac{1}{2}}$ to meet o′:

Therefore $t' = \left(\frac{x}{c} - \frac{v}{c} \cdot \frac{x}{c}\right) \Bigg(\; (1 - \frac{v^2}{c^2}\Bigg)^{-\frac{1}{2}} =$

$\left(t - \frac{vx}{c^2}\right)\left(1 - \frac{v^2}{c^2}\right)^{-\frac{1}{2}}$. (B)

These two formulæ (A) and (B) are the two transformation formulæ of Einstein's kinematics. I have assumed the Lorentz contraction to be real, as it amounts to the same thing as to compute these formulæ by beating around the bush as relativists do.

These formulæ are (if we assume that they have any significance for us on the earth) subject to two serious suspicions.

1. They are deduced on the theory that x′ contracts in accordance with the Lorentz coefficient. Eddington says (and if anyone can command relativity confidence, he can): "There is no experimental proof that a body such as the earth will undergo the theoretical contraction owing to motion. The Michelson-Morley experiment is necessarily confined to solids of laboratory dimensions." In that Eddington is entirely right. Einstein agrees that Lorentz' explanation of contraction is not valid, but makes it contract any way by solving equations.

2. They treat these bodies as not having in their assumed velocity any velocity of the medium in which, or near which they move. We can conceive of few bodies near the earth's surface that were not on the earth, and so had the earth's motion. Therefore when they received an impulse to set them in motion they had both the velocity they had on the earth and what they got from the impulse. Of course this omission makes no practical difference to us, for we only treat the motion of bodies on the earth as moving with reference to the earth at rest. But if the bodies here treated partake of the earth's motion, the Lorentz

coefficient has no place in the formulæ. The Lorentz contraction theory was invented merely to account for the failure of the Michelson-Morley experiment to show what they expected it to show.

As I have before proved, if we assume that the light used in that experiment partook of the motion of the earth, it would have done exactly what it did do. If it did what it ought to have done there would have been no need to explain its failure, for their was no failure, and hence no need for a Lorentz coefficient. In a similar way these bodies partake of the earth's motion; therefore since here there is no question about its moving with the earth's motion, therefore there is no need for the Lorentz coefficient. But these formulæ are the very cornerstone of relativity.

EINSTEIN'S ADDITION OF VELOCITIES FORMULÆ

We shall dwell at considerable length on Einstein's illustration of his proof that the law of the parallelogram of velocities is not a law, and that to add two velocities in the same sense together does not generally give their sum in the following chapters. But in connection with Einstein's kinematics it is worth while to show his mathematics for it. It is the more important, for without these equations bodies cannot have *physical reality.*

Cunningham says: "We may not conceive of a body as having physical reality unless the velocities of a given point as seen by two observers are related to one another and to the relative velocity of the observers by the Einstein Addition Formulæ."

In figure v there are two men, A and B, A on the fixed system S and B on the platform S′, which is moving with velocity v. They agree to start at the same time from the origin O and travel to the point D. A's rate of travel is w and B's is w′ with reference to his axis O′, which is faced to the platform. When they reach D, A reports that he has traveled t seconds and the distance is $x = wt$. B reports that he has traveled t′ seconds and his distance from O′ is $x' = w't'$. Now, in order to compare lengths and times we must substitute for x′ and t′ from formulæ (A) and (B). We have therefore two equations from which to make comparison. (1) $x = wt$. (2) $x' = w't'$. Substituting in (2) we have (3) $x - vt = w' (t - \frac{vx}{c^2}$.

Substituting from (1) we have (4) $x - \frac{vx}{w} = w' \left(\frac{x}{w} - \frac{vx}{c^2} \right)$. Solving for w, we have (5)

$$w = \frac{v + w'}{1 + \frac{vw'}{c^2}}. \quad (C)$$

Thus the outcome is that B's velocity with reference to S is not the sum of his velocity with reference to his axis and the velocity of that axis with reference to S.

From (C) two propositions are drawn by relativists.

1. "If two velocities, each of which is less than c be combined, the resultant velocity is also less than c." If we exercise our common sense we pronounce it absurd to say that if two velocities are each nearly equal to c their sum is necessarily less than c. But that is what the formula will show. Thus if $v = \frac{3}{4}c$ and $w' = \frac{3}{4}c$, the combined result $w = \frac{24}{25}c$.

2. "If velocity c is compounded with velocity

c the resultant velocity is c." If $v = c$ and $w' = c$, in the formula, $w = c$, so much the worse for this formula. When an equation in mathematics gives us absurd results we generally examine the process used in deducing it and the assumptions upon which we have proceeded. I have already given my reasons for its suspicious results.

CHAPTER VIII

EINSTEIN'S SPECIAL RELATIVITY

In commenting on Einstein's explanation of relativity it is but fair that what he has written be given in his own words. In 1916, with the purpose of extending the circle of twelve "who could read and understand his theory," he published a volume, which, while "making no pretence of withholding from the reader difficulties which are inherent to the subject," yet "spared no pains in his endeavor to present the main ideas in the simplest and most intelligent form, and on the whole in the sequence and connection in which they actually originated." In May, 1920, Einstein delivered a lecture at the Imperial University at Leiden on the subject of "Ether," in which incidentally he gave his most recent views of various parts of his theory. I give the salient points in his theories.

I. "FOR A BODY IN MOTION THERE IS NO SUCH A THING AS AN INDEPENDENT PATH-CURVE, BUT ONLY A PATH-CURVE RELATIVE TO A PARTICULAR BODY OF REFERENCE."

He illustrates in this way: "I stand at the window of a railway car, which is travelling uniformly, and drop a stone on the embankment without throwing it. Then, disregarding the influence of the air resistance, I see the stone descend in a straight line. A pedestrian who observes the misdeed from the foot path, notices that the stone falls to earth in a parabolic curve. I now ask: Do the positions traversed by the stone lie 'in reality on a straight line or on a parabola'?"

As Einstein bases his question on what two supposed observers saw, we need to ask what they did see?

He says the man in the car "sees the stone *descend* in a straight line." He sees nothing of the kind.

First. If he can only see the stone, and not the ground or any other surrounding objects, he sees the stone just below his eye for about a second and then suddenly disappear. The stone as it leaves his hand, has the same velocity forward as the car and the observer's eye, and so moves right along below his eye. Since its motion toward the ground at the same time is directly in his line of sight, he does not know that it is going away from him. When it strikes the ground its forward motion is instantly arrested and it suddenly disappears from his sight. He does not see any straight line of descent.

Second. If the man can see the ground directly under the stone all the time the stone is falling, he sees the stone seeming to run along the ground for a second or so keeping directly below his eye, and then suddenly stopping.

Again, he says: "A pedestrian on the footpath notices that the stone falls to the earth in a parabolic curve." He may or he may not. He may be just as much fooled as the man on the car. If he stands beside the track so as to be in the plane of the stone's path, he will see the stone fall down in a straight line as long as from the man's hand to the ground. If he stands so as to get a "square" view of the path of the stone, he sees it describe a parabola.

Einstein's question therefore may be, does the stone just run along below the man for a second and then disappear, or does it run along the ground in a straight line, or does it describe a parabola?

Most people would say, "Oh! Einstein, what a joker you are."

Einstein answers his own question in this way: "The stone traverses a straight line relative to a system of co-ordinates rigidly attached to the car, but relative to a system of co-ordinates rigidly attached to the ground, it describes a parabola. It is clearly seen that there is no such thing as an independently existing trajectory, but only a trajectory relative to a particular body of reference."

This is a fair sample of the non-sequitur conclusions which characterize a large part of Einstein's reasoning.

First, if the man in the car could see the ground below the stone during all the time of its fall it would *seem* to traverse a straight line along the ground. But it did not "traverse a straight line" along the ground or along any other body. As it ran along below the man's eye its various positions in its parabolic path seemed to be in a straight line on the ground.

Second. We wonder if Einstein really thinks that his illustration proves that "there is no such thing as an independently existing trajectory." It simply illustrates what every college student of orthographic projection knows that it is a rare thing if a single view of a surface gives us a complete picture of it. We have just the same case in the Torricelli experiment. In the beautiful Torricelli experiment a tall pipe kept full of water has an orifice made in the side of the pipe some distance from the top. The water spurts out and falls to the ground in a parabola (leaving out air resistance). The man sitting on the top of the pipe and looking down on the stream of water issuing from the orifice might think he sees a stream of water lying on the ground, but the observer looking at it from the side sees a fine parabolic curve. If the man at the top of the pipe is foolish enough to think the parabola is a ribbon of water on the ground, most people would think that does not make it a ribbon of water on the ground, but that there is such a thing as "an independently existing trajectory."

One of the most troublesome phases of the problem of finding the true orbit of the components of a double star is that the observer can get but one view of the orbit. He cannot tell whether he is looking square on the orbit or at what angle it is inclined to his line of sight. But the astonomer never doubts that there is such a thing as an independently existing orbit, and he is troubled because he cannot get where he can see its real shape.

Einstein clinches his argument that there is "no such thing as an independently existing trajectory" by his favorite appeal to ill going clocks. He says, "In order to have a *complete* description of the motion we must specify how the body alters its position *with time.* For every point on the trajectory it must be stated at what time the body is situated there." The only way he can think of to solve the problem is by use of two clocks, one in the hands of the man in the car and the other in the hands of the foot man. "Each of the observers determines the position on his own reference body occupied by the stone at each tick of his clock." He rejects this method because the car man's clock is not reliable—running slow. If it were worth while we might suggest various ways of finding the *real path* of the stone. (1) To obviate the uncertainty about the car man's clock, arrange an overhanging shed in which a man with his clock notes the horizontal position of the stone at each tick. A man just beside the track and in the plane of the stone's path notes, at each tick, the height of the stone. From the two co-ordinates each position of the stone can be constructed. This gives the car man's watch a complete alibi. (2) A blackboard might be set up parallel to the track and near enough to it so that a piece of chalk on the stone would touch lightly the board and trace its curve. (3) The importance of the case does not justify all this trouble. Let the car man ask the foot man: "What kind of a path *did the thing take* anyway?" He would say, "a *parabola* of course. I got a good square look at it."

Of course these methods of getting the form of the curve with reference to the earth are not in accordance with relativity's two system method, but they do answer the question whether there is a real curve with reference to the earth.

II. THE SUM OF TWO VELOCITIES V AND W IS NOT V + W.

We have met this strange statement before in "Einstein's Kinematics," but I give it here as a part of his train and embankment illustration. He illustrates in this way:

"Let us suppose that the railway car is travelling along the rails with a constant velocity V, and a man is walking the length of the car in the direction of travel with velocity W. With what velocity S does the man advance relative to the embankment? The only possible answer seems to be that he is advancing relative to the embankment so as to cover the distance $S = V + W$ in the second considered. We shall see later that this result which expresses the theorem of the addition of velocities employed in classical mechanics, cannot be maintained. That the law which we have written down does not hold in reality."

Of course we are consumed with curiosity and eagerness to have the mystery solved. We must wait. But meantime visions of fourth dimensions rise up before us. Has Lorentz contracted the car? Einstein does not like for Lorentz to contract bodies; he wants to do it himself, or let relativity do it. It is not fair to spoil a story by anticipating the outcome, but we shall find that clocks and measuring rods are guilty.

III. C — V IS NOT LESS THAN C NO MATTER HOW LARGE IS V.

This is Einstein's illustrative proof:

"If a ray of light be sent along the embankment, the tip of the ray will be transmitted with velocity C with reference to the embankment. The railroad car is moving along in the same direction with velocity V. Let us enquire about the velocity of propagation of the ray of light with reference to the car. It is evident that we can apply the consideration of the man and the car, since the ray of light plays the rôle of the man walking along relatively to the car. The velocity of the man relative to the embankment is here replaced by the velocity of light relative to the embankment. C is the required velocity of light with respect to the car, and we have $C' = C - V$. The velocity of a ray of light relative to the car thus comes out smaller than C. But this result comes in conflict with the principle of relativity. For the law of the transmission of light in vacuo must, in accordance with the principle of relativity, be the same for the railway car as reference-body as when the rails are the reference-body. At this juncture enters the relativity theory."

This looks like another of Einstein's jokers.

1. He says: "It is evident that we can apply the consideration of the man and the car illustration, for the ray of light plays the part of the man walking relatively to the car." On the contrary it is evident that it is not the same condition at all. The ray of light is not travelling in the car as the man is. Hence it is not subject to being misjudged by any error in clocks or any misbehavior of rods, as we shall find that Einstein charges upon the man and car. Both ray of light and car are sent along beside the embankment, one with C velocity, the other with V velocity. The problem, then, is just as if two engines start at the same point and travel along two parallel tracks, one with C velocity, the other with V velocity. How far will they be apart at the end of a unit of time? Until we have some more convincing proof to the contrary, we shall say they will be a distance apart of C —V. And in like manner say that the *tip* of the ray will be C — V ahead of the car in a unit of time.

2. Einstein starts out with the "tip" of the ray running a race with the car, and then loses sight of the tip of the ray and introduces a postulate about the invariance of light velocity, which has nothing at all to do with this illustration. The illustration as given does not deny or affirm the invariance of light velocity.

3. Einstein might have made his illustration in this way, and there would have been no question about the invariance of the velocity of light. Suppose that at the instant the car passes a point O on the track, there is a murder at O on the track, and a fight on the car. The light from each starts out in hunt for a policeman. Now Einstein assumes that the speed of light is independent of the velocity of its source, and once it is started it has nothing more to do with its source. If so, the murder "tip" and the fight "tip" will travel side by side, and at the end of a second will still be side by side.

Now, after we have fixed up the matter of invariance of light velocity, if anyone says that when one of these tips reaches a point C distant from the starting point it is just as far ahead of the car as if the car had stood still, or had no velocity, we do not believe him however he may camouflage it.

4. If a moving body cannot gain on light

however fast it moves, how can Eddington "achieve immortality by cruising around with velocity of light"? How cruel the disappointment of those who have planned to live forever by getting in a box and travelling away with the velocity of light, with eye fixed on the hands of a clock, when they find that the light from the moving hands continually catches up with them just as if they had stayed at home and were compelled to grow old there.

IV. A CLOCK ON A MOVING BODY RUNS SLOWER THAN IF THE BODY WERE AT REST.

In order to be able to tell whether clocks are keeping good time or not, we must have a clear understanding of the proper way to rate clocks. We must know how to determine whether the hands of various clocks start at the same figure simultaneously. Also, whether they stand at the same figure to indicate the difference between events which do not occur at the same actual time. This is the more important in discussing relativity since so much use is made of clocks by Einstein and others.

First. How do we decide whether events are simultaneous?

Einstein leads up to his test by an illustration.

"Lightning has struck the rails by the embankment at two places A and B far distant from each other. I make the assertion that the two lightning flashes occurred simultaneously. When asked to explain what is meant by the statement that the two flashes are simultaneous, we find that the answer to the question is not as easy as it appears at first sight." Finally it is determined to try the following method: Measure the distance A B and find the point U midway between A and B. The observer at U is supplied with an arrangement by which he can see A and B at the same time. "If the observer perceives the two flashes at the same time then the two flashes are simultaneous."

Then the question is raised that the flashes may not have *occurred* at the same time, as it might have taken light longer to come from A to U, than from B to U. The final conclusion is that the seeing the two flashes at the same time is the proper test of simultaneity. "Because in reality it assumes nothing about light. There is only one demand to be made of the definition of simultaneity, namely, that in any real case it must supply us with the empirical decision as to whether or not the conception that has to be defined has been fulfilled. That light requires the same time to traverse the path A U as to traverse B U is in reality neither a *supposition* nor an *hypothesis* about the physical nature of light, but a *stipulation* which I can make of my own free will in order to arrive at a definition of simultaneity."

1. Why did these experimenters measure off equal distances from A and B if they did not have an *hypothesis* about light? They evidently assumed that the *velocity* of light is invariant, and that it would take light as long to traverse A U as B U.

2. They evidently threw away their test which seemed reasonable and now adopt the fulfilment of a *stipulation* as the test of simultaneity of the occurrence of events, stipulations made by the own free will of any erratic observer. There is no objection to anyone adopting any test of simultaneity for himself if it is a mere matter of speculation, or if his tests do not affect adversely anyone. He may assume that runners *reaching* him at the same time *started* at the same time. He may assume that if light from a new star reaches him at the same time as the lightning flash, that the light from the outburst, or whatever started the light from the "Nova," started at the same time as the starting of the lightning flash. It would be frivolous to carry a definition to absurd extremes if it did not outcrop all through rela-

tivity that *reality* is no more important than *appearance*, and that the mistaken notion of the misinformed may with perfect legitimacy be substituted for the truth.

Einstein makes the real test of simultaneity in a way with which little fault can be found. Thus he says:

"Time in physics is thus determined: We suppose identical clocks placed at the points A, B, C, and they are set in such a manner that the positions of their pointers are simultaneously the same. We understand by the time of an event the position of the hands of the clock which is in the immediate vicinity (in space) of the event." His method, therefore, is to declare that two events occurred at the same time if the light coming from the clocks near the events shows the same position of the hands simultaneously. And also the times of occurrence differ as much as is indicated by the different positions of the hands as seen from the same point at which they were rated as simultaneous when the hands agree.

Second. "Events which are simultaneous with reference to the embankment are not simultaneous with respect to the train, and vice versa."

Einstein deduces his proof in this way:

"Suppose a very long train travelling along the rails with constant velocity V. Are two events

(e. g. the two strokes of lightning A and B) which are simultaneous with reference to the embankment, also simultaneous *relatively to the train?* The answer must be negative."

Two points A′ and B′ on the train are taken just as far apart as the points A and B on the embankment. U is the mid-point of A B on the bank and U′ mid point of A′ B′ on the train. Just at the instant that U′ is opposite U suppose the two flashes at either A and B or A′ and B′ occur. The ray of light is coming on from B toward U and from A coming on from the rear. They arrive at U at the same time and would have reached U′ at the same time if U′ had stayed opposite U. But the observer at U′ is moving on to meet the ray from B and riding ahead of the ray from A. The ray from B will not have as far to travel to reach U′ as will the ray from A to overtake U′. "Hence the observer will see the beam of light emitted from B earlier than he will see that emitted from A. Observers who take the railway train as their reference-body must come to the conclusion that the lightning flash B took place earlier than the lightning flash A." Hence he concludes: "Every reference-body has its own particular time. Unless we are told the reference-body to which the statement of time refers, there is no meaning in a statement of the time of an event. Now before the advent of the theory of relativity it had been tacitly assumed in physics that the statement of time had an absolute significance, that is, that it is independent of the states of motion of the body of reference. But we have seen that this assumption is incompatible with the most natural definition of simultaneity."

1. As to the general statement, "unless we are told the reference-body to which the statement of time refers, there is no meaning in the statement of the time of an event," no one ever thought of denying it. If I say: "The moon crossed my meridian at eight P. M.," it doesn't mean anything to my correspondent unless he knows which of all the infinity of meridians I do have as mine. If I say to my Chinese correspondent that we go by Eastern Standard time, it doesn't mean anything to him until he knows, for instance, how far my standard meridian is west of Greenwich.

2. As to the fact that the two flashes did not reach U′ at the same time being "incompatible with the most natural definition of simultaneity," it might probably be brought into complete agreement with Einstein's own test of simultaneity. When they were testing U, the point midway of A and B and the objection was raised that the

fact that flashes *reach* U at the same time might not prove that they *occur* at the same time, as it might take longer for light to traverse A U than B U, it was decided that it didn't make any difference. They had a right "of their own free will" to decide what conditions would have to be fulfilled to test simultaneity. Well, if so, why might not the passengers in the train "of their own free will" determine that all flashes that reach them at a difference of ten seconds, for instance, were simultaneous. Of course that is absurd, but hardly as absurd as Einstein's statement of the test of simultaneity.

3. This illustration proceeds on the assumption that this ignorance of the passengers was in some way due to their motion. It was not due primarily to motion, but to the fact that the car was not midway of the two points A and B. Everybody knew that long before anybody talked about relativity. The man sitting at his window and in the storm hears the peals of thunder coming from all parts of the heavens. If he has a reasonable amount of sense he will not assume that the peals which come to him at the same time, started at the same distance from him, nor that those that come at different times may not have started at the same time.

4. The real point, at least the most used, is

the assumption that the illustration shows that the clock on the train is running slower than if it had been at rest.

In the first place, the illustration does not show that the time indicated by the clock on the train when flashes A and B came was not just what it ought to be. If the difference of time shown by the clock on the train when B flash reaches it, and the time B's flash reaches U is just the time it takes light to travel from U to where U′ is, the clocks are keeping the same time. Nothing in the illustration as given contradicts it.

In the second place, the fact that the clock on the train showed earlier when B flash reaches it than when flash from A reaches it raises a presumption that the train clock is keeping good time. If both flashes had reached U′ at the same clock time, the clock would have been very bad, or if they had reached U′ at a wrong interval of time.

5. The fact that the motion of the earth contributed to make two simultaneous events seem non-simultaneous was made use of long before relativity was invented. Astronomers made use of the motion of the earth in its orbit and the eclipses of one of Jupiter's satellites to find the distance from the earth to the sun. When the earth was on the side of its orbit nearest to Jupi-

ter, the time of the eclipse of the inner satellite was noted. Then the earth moving along in its orbit in the part of the orbit nearly parallel to Jupiter was, at the end of forty-two and a half hours at the same distance from Jupiter as it was at the time of the former eclipse. An eclipse of the same satellite is now again observed. The same simultaneous interval (so to speak) between two eclipses was therefore forty-two and a half hours. Now the earth starts to travel along the side of its orbit which stretches away from Jupiter. The earth is moving away from Jupiter and is further away from him when each eclipse occurs than it was when the preceding eclipse occurs. Therefore the time between two eclipses is forty-two and a half hours plus the time it takes light to travel the distance the earth has moved in forty-two and a half hours. So each period was longer than forty-two and a half hours by about ten seconds, until when the earth had reached the part of its orbit farthest away from Jupiter. The sum of all these differences from forty-two and a half hours had amounted to about one thousand seconds. Hence it takes light one thousand seconds to cross the earth's orbit. Therefore the breadth of the orbit is one thousand times 186,000 miles, or 186,000,000 miles.

V. EINSTEIN RETURNS TO THE PROOF THAT V ADDED TO W IS NOT V + W.

Einstein assumes that he has proved his contention about time and now returns to clinch his proof that V added to W does not give V + W in reality. He says:

"In the former section we concluded that the man in the car, who traverses the distance W per second relative to the car, traverses the same distance also with respect to the embankment *in each second of time.* But according to the foregoing considerations, the time required by a particular occurrence with respect to the car must not be considered equal to the duration of the same occurrence as judged from the embankment. Hence it cannot be contended that the man in walking travels the distance W relative to the railway line in a time which is equal to a second as judged from the embankment." Then he introduces a second attack: "The length of the train as measured from the embankment may be different from that obtained by measuring in the train itself. If the man in the car covers the distance W in a unit of time—*measured from the train*—then this distance—*as measured from the embankment*—is not necessarily also equal to W."

The above quotation scarcely needs comment. After wading through the illustrations given preparatory to a return to the proof that V plus W is not V plus W, the final outcome is disappointing. However, it is about as anticipated, for the proof is based on two things, unreliable clock and contracted car.

1. He says: "According to the foregoing considerations, the time required with respect to the car must not be considered equal to the duration of the same event as judged from the embankment." As I have before shown, there was not a scintilla of proof in the illustrations given that the tick of the car man's clock did not absolutely synchronize with the tick of the foot man's clock. The only thing that seemed to look toward a proof according to Einstein, was the fact that light starting from B reached U′ sooner than U because U′ was nearer than U. Indeed the only inference from the illustration that could be fairly made is that the clocks were synchronized because they showed the real difference of time between the ray reaching U′ and U.

2. He says: "The length of the train as measured from the embankment may be different from that obtained by measuring in the car itself." It is rare prudence to have two arrows in the quiver. If one misses the other may hit. If a poor clock will not help out, an elastic car "may." It seemed rather spiteful when I said

before that Einstein does not want Lorentz to contract the length of a car, for he wants to do it himself. Lorentz shortens the car by flattening its electrons into ellipsoids and huddling them together; Einstein shortens it by substituting in an equation of transformation. Many persons would prefer Lorentz' bold hypothesis to Einstein's, which, while denying Lorentz' theory, gets, as he says, his result "by means of the first equation of the Lorentz transformation," and reaches the conclusion: "It therefore follows that the length of a rigid metre rod moving in the direction of its length with velocity V is $\sqrt{1-\frac{v^2}{c^2}}$ of a metre. The rigid rod is thus shorter when in motion than when in rest, and the more quickly it is moving the shorter is the rod. For the velocity V equals C we should have $\sqrt{1-\frac{c^2}{c^2}}$ $= 0$, and for still greater velocities the square root becomes imaginary.

In comment we might say, in the first place, if it is generally accepted that a length in a moving body has to be divided by $\sqrt{1-\frac{v^2}{c^2}}$ to get its real length, then no honest experimenter on the train would turn in to his boss on the bank an uncorrected length any more than an engineer would turn in a length uncorrected for temperature, sag in his chain, etc. Of course that assumes that he knows he is moving though.

In the second place the engineer would want a much better proof that the coefficient of expansion from heat is a real value than either Lorentz or Einstein (especially Einstein) has for his coefficient.

In the third place one stands aghast at the recklessness of Eddington and others who propose to get into a box and cruise around with velocity of light. "For a velocity $V = C$ the rigid body has no length and for a greater velocity its length is imaginary."

Eddington "achieves immortality by cruising around with velocity of light." Nothing is said in the formula about breadth changing, so Eddington will be a straight line infinitely thin and as long as he was broad. In constant danger of becoming imaginary if by any chance his velocity should exceed C. After all that may turn out to be Einstein's and Lorentz' greatest discovery. A "spiritual body" is a geometrical line as long as Eddington is broad. An age-long theological mystery solved.

But what about Cohen's man and Einstein's who didn't want immortality but just wanted an outing of a few centuries and expected to come back and resume business as usual. He comes back with velocity of light all the time huddled up into nothing. He jumps out of his box (assuming that a "nothing" can jump). He goes careening over the earth until brought to rest by friction and contact with the buildings in his way. Fortunate if his velocity be not too soon arrested, else expanding to normal size he explodes into myriads of electrons.

CHAPTER IX

MINKOWSKI'S FOURTH DIMENSION "WORLD"

Einstein says, "The non-mathematician is seized by a mysterious shuddering when he hears of four-dimensional things, by a feeling not unlike that awakened by thoughts of the occult." If he takes away the "shudder" producing effect of the term fourth dimension it will lose much of its value for certain writers. They can easily play on our imagination. In our school days we were taught that expressions containing two factors represented a surface. If it contained three equal factors, with infinite toil we cut it up into strips and build it up into a cube—a thing of three dimensions. We now find an expression with four factors; surely each factor must represent a space dimension. We try to fit it in, and we find ourselves slipping off into some uncanny hyper-space and we "shudder."

We read the various books written to show that if an equation has more than three factors or terms, it has wonderful possibilities in it. As we have said, an expert in four dimensions can crack a safe without opening it. Can turn a right hand into a left hand—we ought to be very thankful—by just taking it out into fourth-dimension so as not to let the left hand know what the right hand is doing. When we read it all we have a perfect right to "shudder."

But Minkowski's fourth-dimension "world" is not a fearsome thing if properly construed. Unfortunately none of his able and learned expositors seem to have caught its real meaning. Einstein talks of an imaginary co-ordinate having $\sqrt{-1}$ in it.

If they understand the real significance of the theory they carefully conceal it in equations and involved sentences. Properly construed, Minkowski's equations, as far as they have any meaning, dealt with old fashioned space, with old fashioned mechanics of D'Alembert and Lagrange and with old fashioned quaternion operator $\sqrt{-1}$. It is surprising what high value is placed on what they call an "imaginary" scheme. One of them calls it "mind stuff," but still he evidently thinks it valuable mind stuff. "The introduction of such 'mind stuff' as this into physical theory may seem at first to make it rather elusive. But the gain in symmetry makes it possible to anticipate relations which would otherwise probably have remained undiscovered."

Einstein goes him one better. After vaguely describing it, he says: "These inadequate remarks can give the reader only a vague notion of the important idea contributed by Minkowski. Without it the general theory of relativity would perhaps get no farther than its long clothes." If relativity had no other garment than the clothes that he and others wrap around, as they make it from Minkowski's theory, they would not safely pass the policeman at a bathing resort.

As a mathematical conceit, when properly understood, and its results visualized, it is fine, whatever we may say as to its practical value. I propose to briefly outline what I conceive to be its real scheme under two heads.

1. Minkowski's theory applied to statical problems.
2. His theory applied to kinematical problems.

I. MINKOWSKI'S STATICS

Let a particle start from O with uniform velocity C. At the end of time T let it be at D, a point whose rectangular co-ordinates are X, Y, Z, and having moved over the line $C D = C T$. Then (1) $X^2 + Y^2 + Z^2 = C^2 T^2$, or $X^2 + Y^2 + Z^2 - C^2 T^2 = O$.

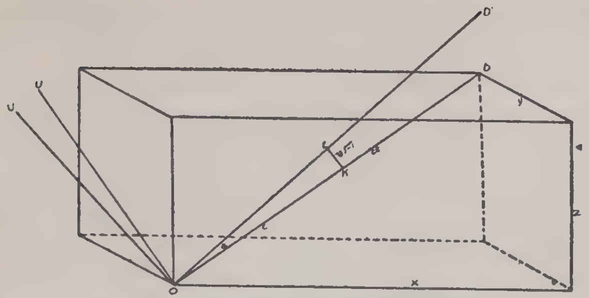

Fig. 6. Minkowski's 4-dimension statics

Now Minkowski says, let (2) $U = CT\sqrt{-1}$. His commentators say that this factor $\sqrt{-1}$ makes it an "imaginary" result. It does not necessarily make the result imaginary at all. In quaternions multiplying by the "operator" $\sqrt{-1}$ simply turns the line through a right angle. Therefore $C\,T\sqrt{-1}$ is merely C T turned at right angles to itself.

Then he says, square $U = C\,T\sqrt{-1}$. Squaring it is introducing the operator $\sqrt{-1}$ again, and

(3) $U^2 = C^2\,T^2$ is $C^2\,T^2$ completely reversed. Substituting U^2 for $-C^2\,T^2$ in the first equation gives (4) $X^2 + Y^2 + Z^2 + U^2 = O$.

This is the much advertised "Fourth Dimension" Minkowski equation.

1. It certainly contains four terms and each

term represents the square of a line, in old fashioned space. But the fourth term is not a *time* co-ordinate, but a space term.

2. It does not mean anything different from what it did before U^2 was substituted for $-C^2 T^2$. For $-C^2 T^2$ meant that the resultant of the three co-ordinates X, Y, Z was reversed. And that is what U^2 means.

3. It is nothing new in mechanics, for

(a) It uses the quaternion "operator" $\sqrt{-1}$ for turning a line force or a velocity at right angles to itself and uses it twice.

(b) It does, in effect, what long ago was done in mechanics, reduce dynamical or kinematical problems to *statical* problems, by introducing a fictitious term equal and opposite to the resultant of the applied forces or velocities.

4. Minkowski's mechanics is called "timeless."

In his statics it is timeless in the same sense as any statical problem is timeless. If all the velocities or forces impressed on a body continually balance, then a few hours or years matter little.

5. They say that "time and space blend into one unity."

Minkowski says: "Time by itself is a shadow, space by itself is a shadow." I hardly think he meant anything, but we may put some meaning in it this way.

The line c t has in it two factors. c is the distance light travels in a second, t is the coefficient of c, showing how many times c is taken. Suppose $t = o$, light cannot go anywhere without a coefficient, and c is but the shadow of what might have been. Suppose, however, that time is all ready to be a coefficient, but light does not go, a coefficient by itself is a "shadow." Let c and t unite and we have the line $o\,d = c\,t$.

I shall give another explanation later.

6. It is said that the triumph of this scheme is that for every system of co-ordinates as X, Y, Z, U and X′, Y′, Z′, U′ $DX^2 + DY^2 + DZ^2 + DU^2 = DX'^2 + DY'^2 + DZ'^2 + DU'^2$. Of course it is not strange, since each set is a statical equation.

II. MINKOWSKI'S KINEMATICS:

Or Minkowski's Mechanics in action.

In the preceding discussion we have seen how his mechanics covers statical problems in the ordinary way. We may now show how it may be construed into a very interesting kinematical conceit and mathematical diversion, which may some day have some value, who can tell.

Strange, unexpected things have happened.

The real Minkowski kinematics may be developed as follows:

(1) The resultant motion of a particle which moves with the velocity of light for time T is the diagonal of the parallelpipedon X, Y, Z as we have before explained, or its position at end of time T is D. (2) The scaffolding X, Y, Z is then thrown away and (3) This line O D is now taken as one of the axes of the rectangular system of co-ordinates in a plane. (4) C T is then turned at right angles to O D by multiplying it by the operator $\sqrt{-1}$. We then have the plane surface D O U in which bodies may be located. (5) Minkowski, after much thought and many trials, we assume, devised a plan by which his equations might have the Lorentz contraction coefficient $\left(1 - \frac{V^2}{C^2}\right)^{-\frac{1}{2}}$. He may accomplish this by revolving the axes O D and O U through an angle *A* constructed as follows: (6) Lay off on O D the line O K = C, then at K erect a perpendicular K E = V $\sqrt{-1}$. (The $\sqrt{-1}$ turns the line V from the prolongation of C at right angles.) Now draw O E D″ through E for a new axis abscissas, and O U′ at right angles to O D′, for a U = — C T axis. Bodies in this plane D′ O U′ will have Einstein co-ordinates and include Lorentz coefficient.

Proof. In the triangle O K E, (1) $OE = (C^2 + (V\sqrt{-1})^2)^{\frac{1}{2}} = (C^2 - V^2)^{\frac{1}{2}} = C\left(1 - \frac{v^2}{c^2}\right)^{\frac{1}{2}}$. (2) $\cos a = \frac{C}{OE} = \frac{C}{C}\left(1 - \frac{v^2}{c^2}\right)^{-\frac{1}{2}} = \left(1 - \frac{v^2}{c^2}\right)^{-\frac{1}{2}}$. (3) $\sin A = \frac{V\sqrt{-1}}{OE} = \frac{V}{C}\sqrt{-1}\left(1 - \frac{V^2}{C^2}\right)^{-\frac{1}{2}}$.

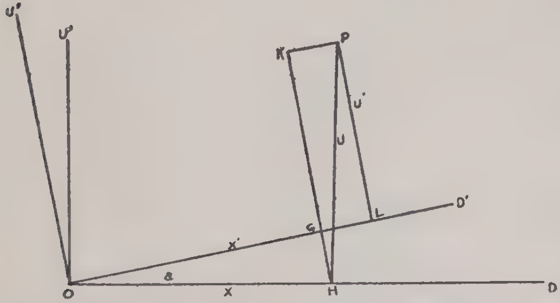

Fig. 7. Minkowski introduces Lorentz coefficient by rotating axes

Now take any point P in the plane D′ O U′—which is also D O U—Draw the co-ordinates for the point P with reference to both O D and O D′. Call the co-ordinates with reference to O D′ U′, X′ and U′, and the co-ordinates with reference to D O U, X and U. From the figure, P L = U′, O L = X′, P H = U, O H = X.

Draw H G K perpendicular to O D′ and P K parallel to O D′. Then

(4) $X' = OL = OG + GL = OG + PK$
$= X \cos a + u \sin a$

(5) $U' = KH - GH = u \cos a - x \sin a$.
Substituting values of sin a and cos a.

$$(6)\ X' = X\left(1 - \frac{v^2}{c^2}\right)^{-\frac{1}{2}} + u\,\frac{v}{c}\sqrt{-1}$$

$$\left(1 - \frac{v^2}{c^2}\right)^{-\frac{1}{2}} = \left(1 - \frac{v^2}{c^2}\right)^{-\frac{1}{2}} =$$

$$\left(X + \frac{u}{c}\,v\sqrt{-1}\right).$$

$$(7)\ U' = u\left(1 - \frac{v^2}{c^2}\right)^{-\frac{1}{2}} - X\,\frac{v}{c}\sqrt{-1}$$

$$\left(1 - \frac{v^2}{c^2}\right)^{-\frac{1}{2}} = \left(1 - \frac{v^2}{c^2}\right)^{-\frac{1}{2}}$$

$$\left(U - \frac{Xv\sqrt{-1}}{c}\right)$$

Substitute for $u' = ct'\sqrt{-1}$ and $u = \sqrt{-1}$ ct, which are the real values of u′ and u in the Minkowski scheme.

$$(8)\ \left(1 - \frac{v^2}{c^2}\right)^{\frac{1}{2}} X' = X +$$

$$\frac{v\,ct}{c}\sqrt{\sqrt{-1}\;\sqrt{-1}} = X - vt$$

$$(9)\ \left(1-\frac{v^2}{c^2}\right)^{\frac{1}{2}} ct'\sqrt{-1} = \sqrt{-1}\,ct - \frac{xv}{c}\sqrt{-1} \quad \text{or}$$

$$\left(1-\frac{v^2}{c^2}\right)^{\frac{1}{2}} t' = t - \frac{xv}{c^2}$$

1st. These are the Einstein relativity co-ordinates in terms of the old system and include the Lorentz coefficients.

2nd. There is nothing "imaginary" or "hyper space" in this entire transformation.

3rd. Time is not a co-ordinate in any new sense. The t in the equation is the multiplier of distance c.

4th. I have made a misstatement when I said Minkowski deduced his result in the way indicated. It is not evident that either he or Einstein looked up from their equations to think what it did mean.

DOES MINKOWSKI'S MECHANICS GIVE GREATER FREEDOM OF DIRECTION?

It is claimed for relativity that it is independent of a system of co-ordinates. The X axis in the Minkowski scheme is practically a directed line.

But after the X O D axis is fixed or assumed, then an *infinite* number of planes are open in which to place bodies and deduce equations for their position.

Let D O U and D′ O U′ be the co-ordinate axis

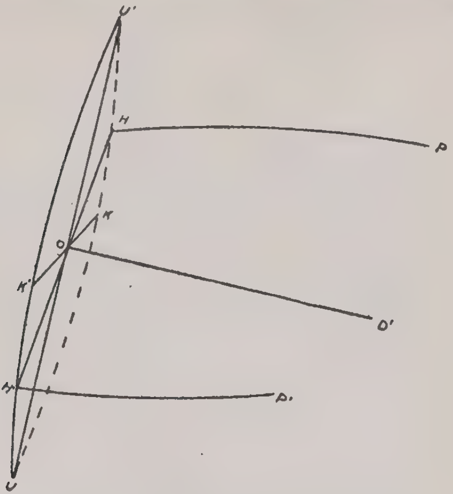

Fig. 8. Minkowski's "world lines"

as we have been discussing them. Since the only condition imposed on the rotation of ct is that it shall be at right angles to O D′, we may rotate it into any one of the infinite lines which radiate from O and which lie in the *plane perpendicular* to O D′. We may have therefore any one of the infinite sets of axes U′ O D′, H O D′, K O D′, etc. Bodies in any of these planes will have Einstein co-ordinates with their Lorentz coefficient. I have accomplished my purpose if I have shown, 1. How a mystery and absurdity is made of an old fashioned space problem. 2. How a pretty gymnastic feat may be spoiled by the performer and his attempted imitators.

CHAPTER X

EINSTEIN'S GENERAL RELATIVITY

It is well at the beginning of the study of General Relativity to restate the fundamentals of Special Relativity in order that the contrast may be more clearly seen and the additions made may stand out. Einstein explains and illustrates special relativity since—to broaden his simile somewhat—it is one of the rooms in his house of General Relativity. Einstein seems to develop his special relativity in three somewhat progressive steps. (1) Relativity of *uniform motion.* (2) Relativity of single *events.* (3) Relativity of the general *laws* of nature.

(1) The "basal principle of special relativity" is the physical relativity of all uniform motion. That is, we may express the motion of an object either with reference to the car or with reference to the embankment if they are in uniform relative motion. The equations and description of the motion of a passenger on the car as made by an observer on the ground is just the same as the description of the apparent motion

of the observer on the ground as seen by the man on the car. (2) It is evident that any event may be referred indifferently to either of two reference-systems moving uniformly relatively. (3) The general *laws* of nature such as the laws of mechanics or the law of the propagation of light in vacuo, *as they are obtained from experience,* may have exactly the same form of expression as referred to either system. In this special relativity all consideration of acceleration, or force, or mass, is excluded. If motion of a body is considered it is in *uniform,* unaccelerated motion unaffected by any impressed force. If mechanics is treated it is purely kinematical mechanics.

In order, as it were, to fix our thoughts, the fictitious assumption is made that (1) we have a reference body K whose condition of motion is such that the Galilean-Newton law holds that a moving "particle left to itself and sufficiently far removed from stars and other masses and all other particles, moves uniformly in a straight line." (2) Any other reference-body shall be exactly equivalent to K for the formulation of natural laws provided they are in a state of *uniform rectilinear non-rotary motion* with reference to the former systems. "The validity of the principle of relativity was assumed only for these reference-bodies, but not for others having a motion of a different kind."

Notice that what they call Galilean or Newton laws are merely the first half of Newton's first law. His first law is: "Everybody continues in its state of rest or uniform motion in a straight line *except in so far as it may be compelled by force to change that state.*" Einstein mentions only the first half in special relativity, and we shall see that he makes no use of the last half in any understandable sense even in his General Relativity.

GENERAL RELATIVITY RECOGNIZES NON-UNIFORM MOTION

Einstein pictures the man in the car as riding along unconscious of his own motion and content to believe that he is at rest and the embankment moving uniformly, and "this interpretation is quite justified on the principles of relativity from a physical point of view." Suddenly he experiences a powerful jerk forward. Brakes have been applied, the retarded motion is shown in the mechanical behavior of bodies relative to him. A new mechanical behavior is introduced. There is now a non-uniformly moving train instead of a uniformly moving train. "The Galilean law does not hold with respect to the non-uniformly moving train. Because of this we feel compelled to grant a kind of absolute physical reality to non-uniform motion. This conclusion cannot be maintained."

1. The Galilean law which he says does not hold is the first half of Newton's first law, "a body continues in a state of rest or uniform motion," but in fact it answers what is implied in the second half "May be compelled by force to change that state."

2. We are puzzled to know how he is going, later, to explain away the physical reality of an *air brake*, a *jerk forward*, and a change of the motion of a train from uniform to non-uniform motion. We hope for much from the next subject.

CHAPTER XI

EINSTEIN'S LAW OF GRAVITATION

Volumes have been written with that sole title. Most of them, including Einstein's most pretentious ones, might more appropriately be headed "vector analysis." The mountains of tensors, covariants, and contravariants labor and bring forth—well, let any of them give a clear cut statement of what they have brought forth.

I. GENERAL CHARACTER OF GRAVITATION

It is essentially of the same nature as the geometrical forces introduced by a choice of co-ordinates. Einstein states it thus: "A gravitational field of force is exactly equivalent to a field of force introduced by a transformation of the coordinates of reference so that by no possible experiment can we distinguish between them."

Eddington gives an illustration from a criticism of Jules Verne's "Round the Moon."

"In Jules Verne's Round the Moon three men are shot up in a projectile into space. The author describes their strange experiences, when gravity vanishes at the neutral point between the earth and moon. Pedantic criticism of such a delightful book is detestable: yet perhaps we may point out that, for the inhabitants of the projectile, weight would vanish the moment they left the cannon's mouth. They and their projectile are falling freely all the time at the same rate and they can feel no sensation of weight. They automatically adopt a new space, referred to the walls and fixtures of their projectile, instead of to the earth. Their axes of reference are accelerated—falling toward the earth: and this transformation of axes introduces a field of force which just neutralizes the gravitational field. According to the principle of equivalence, no effect of any kind could be detected inside the projectile: the gravitational field cannot be differentiated from a transformation of co-ordinates, and therefore the same transformation which neutralizes mechanical effects neutralizes all other effects."

(a) Eddington starts out to convict Jules Verne of ignorance of something he didn't mention. He probably knew that if a man on a spring balance be let fall from a balloon the balance will not register any weight, for it will run away from him as fast as the man can follow.

(b) Jules Verne playful is here as scientific as Eddington serious The humor of Eddington is keener in that he can solemnly assert a thing on one page and knock it to pieces on the next. Jules Verne was right in the only scientific fact that he asserted. The dog and the man and projectile would attract each other and slowly approach each other at the neutral point between the earth and the moon. He overdid the amount of the attraction, but not the fact.

(c) The chief purpose that Eddington had in view in giving the illustration is to illustrate Einstein's postulate of equivalence, that "a transformation of the co-ordinates of reference introduces a field of force exactly equivalent to a gravitational force."

We ought to be, but we are not surprised when Eddington immediately follows this illustration by the statement: "It is clear that we cannot transform away a natural gravitational field altogether. They were concerned with a practically infinitesimal region, and for an infinitesimal region the gravitational force and the force due to a transformation corresponds; but we cannot find any transformation which will remove the gravitational field throughout a finite region. It is like trying to paste a flat sheet of paper on a sphere, the paper can be applied to a point, but as you go away from the point you soon come to a misfit." We wonder why he used the illustration if it did not mean anything. Notwithstanding his assertion that a transformation of co-ordinates does not equal a gravitational field, he endorsed Einstein and assumes that all you have to do to discover a law of gravitation is to make a new set of differential equations arising from a transformation to a certain set of axes.

2. AS MANY POSSIBLE LAWS OF GRAVITATION, AS POSSIBLE TRANSFORMATIONS OF AXES OF REFERENCE

Having settled it that the law of gravitation is concealed in some set of equations found from transforming the equations belonging to a set of axes, such as the Galilean set or the set which is moving uniformly, Einstein set to work to uncover a set of equations that would satisfy him. The whole infinity of transformations invite him, but he chose one for mathematical reasons.

First. According to the postulate of equivalence, he assumes that in all transformed systems the distance d s between two consecutive points has the same value. This took away from the process that he pursued some of its arbitrariness. It gave to the discussion a certain definiteness of direction. If all equations of transformation must be so construed as to give the same value for d s, it would seem that in the pursuit we are tending toward a unique law of gravitation.

Second. Einstein used four dimensions in his equation, three of these the regular Cartesian co-ordinates, the fourth dimension is time. Out of these four dimensions he made an equation of ten terms in which the square of this d s is set equal to a combination of the squares and products of the differentials of these four dimensions. Each term of the ten had a variable coefficient.

It is evident that by varying these coefficients, hundreds of equations could be made out of the ten. Einstein calls the system of reference he chose a "mollusc." It seems a rather appropriate name, not only because its yielding softness is characteristic of these flexible coefficients, but if a snail meets a hard place it can draw its head into its shell, and move awhile with no visible head.

Third. Einstein manipulates this assumed equation, eliminating, transforming, approximating, often with no apparent end in view, giving a wonderful exhibition of his skill in vector analysis, arousing our sympathetic interest in the courage he shows in enduring the pangs of the Birth of a New Law of Gravitation. Out of all this he deduces an equation for this d s which has a term more than Newton's value for the same: also for a ray of light passing the Sun he has multiplied by two the value of the deflection computed by Newton's law of attraction.

These results I have discussed in another connection, and I shall refer to them later.

CHAPTER XII

THE GRAVITATIONAL FIELD FOR NON-ROTATING BODIES

"If we pick up a stone and then let it go, why does it fall to the ground?" The usual answer is, because it is attracted by the earth. Modern physics answers differently. We have come to regard action at a distance as impossible without the intervention of a medium. The action of the earth on the stone takes place indirectly. The earth produces in its surroundings a gravitational field which acts on the stone and produces its motion of fall."

1. This is a characteristic explanation. The earth cannot act at a distance, it just surrounds itself with a *gravitational field,* and then lets "gravitational field" do it. Or, as he says in another place, the earth produces a "strain in space." Then this strain in space gathers in stones.

2. What is this medium? What is the difference between empty space and strained space?

Why do bodies near the earth appear to be attracted to it? The illustration which Einstein gives can scarcely be abridged without spoiling it.

"We imagine a large portion of empty space so far removed from stars and appreciable masses that it is possible to choose a reference-body relative to which points at rest remain at rest and points in motion continue in uniform rectilinear motion. As reference let us imagine a spacious chest resembling a room, with an observer inside. *Gravitation does not exist for him.* He must fasten himself to the floor with strings or the slightest impact against the floor will cause him to rise slowly toward the ceiling of the room. To the middle of the lid of the chest is fixed externally a hook with a rope attached. Now a being begins pulling at this with a constant force. The chest, along with the man, begins to move 'upwards' with a uniformly accelerated motion. In course of time it might attain unheard of speed, as seen from another reference-body which is not being pulled by a rope. The acceleration of the chest will be transmitted to the man by the pressure of the floor of the chest. He must take up this pressure by means of his legs. He is then standing in the chest in exactly the same way as anyone stands in a room on our earth.

If he release a body which he previously had in his hand, the *acceleration* of the chest will no longer be transmitted to this body, and for this reason the body will approach the floor of the chest with an accelerated relative motion. The man in the chest will come to the conclusion that he is in a gravitational field." That is, he will conclude that the chest attracts him. If he sees the rope he will think that it is just holding the box at rest, and that the chest attracts him. "We must admit that his method of grasping the situation violates neither reason nor mathematical laws. Though the chest was accelerated we may regard it as being at rest. We have good grounds for extending the principle of relativity to include bodies of reference which are being accelerated with reference to each other, and have gained a powerful argument for a generalized postulate of relativity."

As far as this illustration is understandable it seems to have two purposes in view, (1) To furnish a powerful argument for a generalized postulate of relativity." Thus, he has invented a fictitious illustration to show that an observer on an accelerated body would get the same result if he formed equations and described the *apparent* accelerated motion of a body at rest, as the observer on the body at rest would get if he formed equations and described the *real* motion of the accelerated body. So far so good.

(2) The main purpose of the illustration, however, is to explain the meaning of *gravitational field* near the earth for a non-rotational motion.

(a) APPARENT PULL DOWN IS REAL PUSH UP

If I stand on a spring balance and find that the indicator shows that I am pressing on the balance by what I call one hundred and fifty pounds, I do not press down one hundred and fifty pounds on the spring, but the earth shoves up against my feet, and it takes what I call one hundred and fifty pounds pressure to keep me moving with an acceleration of thirty-two feet per second. This is evident from the statement: "He must take up this pressure by means of his legs." It is more fully illustrated in this quotation: "Suppose that the man in the chest fixes a rope to the inner side of the lid, and that he attaches a body to the free end of the rope. The result is to stretch the rope so that it will hang 'vertically' downwards. If we ask for the cause of the tension in the rope, the man in the chest will say: 'The suspended body experiences a downward force in the gravitational field and this is neutralized by the tension of the rope: what determines the magnitude of the tension of the rope is the gravitational mass of the suspended body.' On the other hand, an observer poised freely in space will interpret the condition of things thus: 'The rope must perforce take part in the accelerated motion of the chest, and it transmits this motion to the body attached to it. The tension of the rope is just large enough to effect the acceleration of the body.' This is almost as complete as the house that Jack built. A being pulls the outside rope, the rope pulls the lid, the lid pulls the inside rope, the rope pulls the body tied to its end."

Einstein says: "The chest, as seen by an observer poised in space, may "attain unheard of velocity." So it would. If it had been moving at that rate of acceleration for only a year, it is now moving at a billion miles a second, or fifty-four hundred times the velocity of light. If we, going head on with that velocity, are contracted according to the Lorentz coefficient we are reduced to unimaginary size, much less than nothing. A reader says: That is unutterably silly. Certainly it is. But if that is not what Einstein means, let the reader guess what he does mean. If he does not mean that the earth's apparent gravitation is due to its acceleration upward, what does he mean? If a billion miles velocity is too great, when did the earth begin to be accelerated.

(b) A FREE BODY NEAR THE EARTH DOES NOT FALL DOWN, THE EARTH FALLS UP

A man up in a tree is being accelerated "upwards" with acceleration of thirty-two feet per second. He pushes an apple from a branch. The apple had the same velocity that the tree and earth had just as it was pushed off the branch. When free it keeps on upward with that *uniform* speed. While the apple moves on with uniform speed, the earth moves on with speed which increases thirty-two feet each second, and soon catches up with the apple. The man on the tree thinks the apple fell down. The observer, "poised in space," sees that the earth pursues the apple and catches up with it.

In all honesty of thought we ask: 1st, Since people are weighing themselves on spring balances, are pushing apples off of branches, are hanging bodies up by ropes, all around the earth, how can all these phenomena be caused by the earth moving sidewise, forward and backward all at one time? 2nd, What, in fact, is the force which pulls the rope, or causes the earth's acceleration?

In another connection Einstein speaks of the gravitational field outside of the "domain" of the body which is being considered. We might suppose that this gravitation from outside bodies, as the stars, for instance, might furnish the rope but for two things: (1) The force would have to be exerted at a distance, which Einstein does not allow. (2) Why does not this outside gravitational field act on the apple and accelerate it just as much when it is not on the branch as when attached to the tree?

CHAPTER XIII

EINSTEIN'S EXPLANATION OF CENTRIFUGAL FORCE AS GRAVITATIONAL

He has, to his satisfaction, explained *rectilinear* acceleration by a *gravitational field,* without undertaking to account for that gravitational field, any more than we can gather from his crude illustration of the box as the accelerated body, and the "being" pulling the rope as the gravitational field.

Now he undertakes to turn the centrifugal force in a rotating body into the effect of a gravitational field. Our imagination is now enough quickened that we can supply the rope and the "being." This is the illustration, and it is a favorite one with him, just as the box and rope is a favorite illustration.

"Imagine a plane circular disc which rotates uniformly about its center in its own plane. An observer while sitting eccentrically on the disc (which we will call K′), is sensible of a force which acts outwards in a radial direction, and which would be interpreted as an effect of inertia (centrifugal force) by an observer at rest on an original reference body K. But the observer on the disc may regard his disc as at rest. He regards the outward pull as the effect of a gravitational field. The gravitational field is of a kind not possible in Newton's theory of gravitation. Since he believes in the general theory of relativity, it does not disturb him. He is quite right when he believes that a general law of gravitation can be formulated, a law which not only explains the motion of the stars, but also the field of force experienced by himself."

1. Here, as in all Einstein illustrations,—and as relativity requires—we have a simple-minded man on a body K′, who is ill-informed about what is going on in his system. We are anxious that he be aroused to the danger of his having bad clocks and bad yard-sticks. So a guardian is placed on another body K, who, untroubled by the false things on his own system—they are just as bad if he only knew it as seen by observer on K′—undertakes to find out what is wrong on his neighbor's system and kindly tell him how much wrong are his clocks, measuring rods, and his notion of the forces at work on his system. The judgment of the guardian is generally wrong, as is ordinarily the case when

a man meddles in other people's business. Einstein always puts us on our guard. He says: *"As seen by the man on system K."* Then, almost at once, forgets that warning, and affirms the judgment of the guardian as *absolutely demonstrated reality.*

In the illustration just given, however, he entirely reverses his usual method and tells the simple man to entirely disregard his guardian, and that he is "quite right that a general law of gravitation can be formulated" which will prove that he is right.

Since Einstein encourages a ward to rebel against a guardian, it forebodes the destruction of relativity. The whole theory is based on guardians and wards. What is the use of guardians if their decision does not stand? Before we allow such fatal result we must see that justice is done to this guardian.

2. The observer from the outside system K, calls the outward pull as due to what he and we call *Centrifugal Force.* He believes that this outward pull experienced by the man on the disc illustrates Newton's first law in its *entirety.* Thus (a) The man sitting on the edge of the rotating disc at a certain point is moving forward with uniform speed and "would continue to move with uniform motion in a straight line," along the line

drawn tangent to the disc at that point. If some mischievous imp would slyly grease the disc, the man would slip off the disc and start on a journey along the tangent. (b) But now comes in the second half of Newton's first law: "Unless by some force it be compelled to change that state of motion." The man on the disc is fastened to it, glued to it perhaps. Every particle of him above his glued feet tends to keep on in a straight line according to the first half of Newton's law. The disc adheres to the glue, the glue adheres to the bottom of the man's feet. The bottom of the feet coheres to the next layer of his feet, and so on each layer coheres to the next higher layer, on up to his head, and each layer holding on to its neighbor and pulling it in. This apparent outward pull is what must be overcome to turn the body from a straight line. If the speed is great enough to make this tendency to keep on in a straight line more than the coherence of the parts of his body, off goes his head in a tangent, and bit by bit goes his body on down to the glue. Far less painful would be the result if he could imitate the grindstone under like conditions, and explode at once.

If such be what the guardian means by "centrifugal force," we are constrained to side with him against his ward and Einstein. If Einstein is not convinced, the matter might be submitted to experiment. Let a rapidly rotating disc be provided and a body be fixed on it at its edge. Let the string holding it be suddenly cut and see whether the body goes off via tangent or off radially in answer to the pull of the rope.

3. He says, however, "The man on the disc may regard his disc as 'at rest.' He regards this outward pull as the effect of a gravitational field." He is supposed to be able to test the force at different places on the disc and finds out that Newton's law of the force varying inversely as the square of the distance, does not apply. Einstein says, he will fix up a "general law of gravitation which will explain the field of force experienced by the man." We agree that it is "not of a kind of force to which Newton's law of gravitation applies." The conditions here illustrated have nothing at all to do with what Newton means by gravitation.

CHAPTER XIV

EINSTEIN EXPOSES THE FAULTS OF CLOCKS ON THE ROTATING DISC

The man on the disc places one of two identically constructed clocks at the center of the circular disc, and the other on the edge of the disc, so that they are at rest relative to it.

Are the clocks going at the same rate from the standpoint of the non-rotating reference-body K?

As judged from this body, the clock at the center of the disc has no velocity, whereas the clock on the edge of the disc is in motion relative to K owing to the rotation of the disc. "According to the result we obtained before" (in case of the moving train) "it follows that the latter clock is going at a rate permanently slower than that of the clock at the center of the disc, i. e. *as observed from K.* It is obvious that the same effect would be noted by an observer sitting beside his clock at the center of the circular disc. Thus *on our circular disc, or, to make the case more general, in every gravitational field a clock will* *go more quickly or less quickly according to the position in which the clock is situated (at rest).*"

It is hard to decide where to begin to discuss the fallacies and misleading implications in this illustration.

(1) "It is obvious from the previous proof that the clock at the edge is going at a permanently slower rate than the clock at the center." In reference to this two things need to be said: First. In the illustration from the man in the car there was not a scintilla of proof that the clock on the train was going at a slower rate than the clock on the embankment. In fact, the presumption was that they were going at the same rate since the clock on the train showed that the light from the forward source reached it before it reached a point farther away from the source, and there was nothing in the illustration to show that the difference in times shown by the two clocks was not just what it ought to be. (2) The same kind of no proof is all that can come out of this illustration. Thus, suppose the guardian on the non-rotating platform has a clock identical in construction with that on the edge of the disc. At a certain time the two clocks are set so that the hands of each will stand at twelve as seen by the guardian. They will, it is true, differ at the outstart by the time it takes

light to go from the edge clock to the guardian. After a lapse of time the guardian looks again. He sees that the hands of his clock stand at fifteen minutes after twelve, and the hands of the edge clock stand at fourteen minutes and fifty seconds after twelve. They apparently differ by ten seconds. If the edge clock has moved away from the guardian a distance which it takes light ten seconds to travel, then the clocks are keeping the same time. The light from the hands of the edge clock when it was ten seconds short of fifteen minutes after twelve has just reached him. There is nothing in this illustration to show that the clocks did not run at the same rate. The presumption is that the two identically constructed clocks did keep the same rate, as no physical cause has so far been introduced to effect a change. Of course, if we grant that the observer on K did not know that the clock is going away from him he would *think* the edge clock is running slow, but he does know, as the condition is stated. And if Einstein would let it go *as seen by the observer on K,* we would not object. But in a moment he affirms that it is actually true that the clock is running slow, and says it will go slow in all gravitational fields.

3. "It is obvious that the same effect would be noted by an observer sitting beside his clock at

the center of the disc." "It is obvious" is a very common introduction to the statements which some mathematicians make when they cannot prove the proposition. This proposition is much different from the one referring to the guardian on K. Here the edge clock is always at the same distance from the center clock. There is no question as to the different lengths of time it takes light to travel from the hands in the different positions. The only basis for Einstein's assertion that the clocks varied was the illustration from the clock on the car and embankment, and that was founded on the different times at different distances from the source of the light. Even if the assumed variations were due to the Lorentz contraction, as the radius does not contract it would make no difference in the time of traversing different radii. If they did contract they would contract alike. It must be kept in mind that the statement made is, "whether both clocks *go* at the same rate," not were they set at the same absolute time. They were set at a real difference of time such as it would take light to go from the edge clock to the comparison clock.

4. Note here, the characteristic method of proof of the grand proposition to which it all led. First. "The latter clock" (the edge clock) "goes at a rate permanently slower than that of the

clock at the center of the disc, i. e. as observed from K." Therefore second, "Thus on our circular disc, or, to make the case more general, in every gravitational field a clock will go more quickly or less quickly according to the position in which the clock is situated (at rest)." In the first case he is careful to limit it to what the *guardian* thought. Then he confidently affirms that the changing rate of the clocks is proved as being really true for the disc. He is now siding with the guardian, before he sided with the ward. Then triumphantly exclaims that clocks are variable in every *gravitational field.* There are only two slight objections to the last statement. 1st, he has not proved that clocks vary on the disc. 2nd, he has not proved that there is a gravitational field on the disc, at least in any so far understandable sense.

We might think that this disc "proof" is used merely as an illustration of the way in which an observer on a rotating body might be deceived about forces at work on his system if he did not know that his system is rotating. But our curiosity was aroused even then when he said that the man on the disc was not fooled, but that the apparent outward pull was a gravitation force, and that this was only a special case of his general science of gravitation.

Einstein fully confirms that theory in an article in a recent number of "Nature."

He says: "All bodies fall in a gravitational field with the same acceleration, that is, the gravitational and inertial masses are numerically equal to each other. This numerical equality suggests identity in character.

Can gravitation and inertia be identical?

"This question leads directly to the General Theory of Relativity. Is it not possible for me to regard the earth as free from rotation if I conceive of the centrifugal force which acts on all bodies at rest relatively to the earth as being a "real" field of gravitation or part of such field? If this idea can be carried out then we shall have proved in very truth the identity of gravitation and inertia. For the same property which is regarded as *inertia* from the point of view of a system not partaking of the rotation can be interpreted as *gravitation* when considered with respect to the system that shares the rotation. According to Newton this interpretation is impossible. My conviction of the identity of inertial and gravitational mass aroused within me the feeling of absolute confidence in the correctness of this interpretation."

1. The "correctness of what interpretation?"

Evidently, that the earth does not rotate and that so-called centrifugal force is produced by a pulling or pushing force, which he calls gravitation.

2. If gravitation is identical with inertia it must connect up in a consistent way with motion in a tangent to the earth.

The idea of the connection of *inertia* in this case is that an inert body cannot stop itself once it is set in motion. If gravitation comes in to take the place of inertia, at every point on the earth it must pull each particle along the tangent to the earth at that point. The component of this force which we get by resolving the tangential force into the radius at that point is zero. So we will have to have a gravitational force acting out in radius produced. Where do these forces come from? Einstein does not tell.

3. He says: "Is it not possible for me to regard the earth as free from rotation?" I did not think it possible, but he knows best. The man on the street does not think of it in other way. Astronomers a few centuries ago could think of the earth as not rotating. The persecutors of Galileo could do it. Francis Bacon could do it; Newton could not.

4. Modern astronomers will have some difficulty in doing it. In addition to having acquired the habit of looking for some physical cause for

a force, they will have trouble with the trade winds, the ocean streams, the ball let fall from the top of a tower which strikes the ground a little east of the bottom of the tower. Foucault and his hundreds of imitators were much fooled when they thought they saw the earth rotating under the swinging pendulum.

But the matter of most grave concern is to find holes enough in the turtle under the earth through which all the hosts of the heavens, many of them untold billions of miles away, can pass as they circle each day about the fixed earth.

To sum up concerning Einstein's gravitation we may say that at first thought the various illustrations and applications seem to conflict. But it seems possible to reconcile them.

First. *We had the earth like a box* pulled "upward" by a rope. The being pulling the rope was supposed to represent some mysterious gravitational force "outside of the domain of the earth," and all we know of it all is the pressure which the earth exerts upon our feet."

Second. A stone let fall from a car falls. "All bodies *fall in a gravitational field* with the same acceleration." But we remember that the stone which the man in the ascending box had in his hand was just *released* and the bottom of the box caught up with it. It *seemed* to *fall* with accelerated motion.

Third. Now we have some force acting on every particle of the earth along the radius at that point produced. That force is in the direction to be consistent with the earth as a box. Its cause is not apparent. But that seems to make little difference to relativity.

CHAPTER XV

VELOCITY OF LIGHT ACCORDING TO RELATIVITY

1. In special relativity one of the two principles upon which it rests is that motion of light in vacuo is *constant in speed and in a straight line.*

2. Pages and chapters have been written in which the Michelson-Morley experiment has been discussed and re-discussed on the theory that velocity of light is constant and not affected by the motion of its source, clocks have been compared and regulated, distances determined and the Lorentz coefficient computed and put into every imaginable result and equation on the same assumption.

If we are new at the study of relativity, and have little experience with the flexibility of its "molluscs" we are surprised to find that this assumption is never true in the *real universe.*

General Relativity denies that it is true in a gravitational field, and we assert that there is no field within our knowledge that is not a gravitational field. General Relativity says the same in its lucid intervals as we have already shown. If this is true, special relativity must at least be modified, the Lorentz coefficient is indeterminate since c is variable.

This is what Einstein says about it: "According to the General Theory of Relativity, the law of the constancy of the velocity of light in vacuo, which constitutes one of the two fundamental assumptions of Special Relativity, cannot claim any unlimited validity. A curvature of rays of light can only take place when the velocity of propagation of light varies with position. We can only conclude that the special theory of relativity cannot claim an unlimited domain of validity; its results hold only so long as we are able to disregard the influences of *gravitational* fields on the phenomena of light."

Let us see how Einstein "proves" that light does not move in a straight line in what he calls a gravitational field:

(a) *By the case of a ray of light moving along a tangent to a uniformly revolving disc.*

A man on the revolving disc is standing on its outer edge. He is not conscious that his disc is revolving. Now a beam of light is sent past the disc in a tangent to the disc. It is moving in a straight line along the tangent as seen from the outside. But the man on the disc is constantly moving away from the tangent as his disc is rotating. He is unaware of his own motion away from the tangent, and thinks that the fact that the beam of light is each instant getting farther away from him is due to the beam's moving in a line which curves away from him. That is, he assumes that *light moves in a curved line with decreased velocity in a gravitational field.*

And that is the first "proof" which relativity gives of the curvature of light. It is a characteristic proof. Einstein accepts the mistaken conclusion reached by the deluded man on the disc, when he has just said that the ray of light is straight as seen by an observer on the outside who is not fooled.

The illustration neither proves that there is a *gravitational* field due to the disc's rotation, nor that the ray of light was *really curved.*

(b) *By means of the man in the accelerated chest.*

Imagine Einstein's box to be divided into, say, five equally spaced vertical partitions in which are slits through which light may pass. Let the partitions be far enough apart that it takes light one-fifth second to pass from one to the other.

First. Let the box be moving "upward" with *uniform* velocity v. This is the condition required in Special Relativity. Suppose a ray of light be started across the box at right angles to its sides, in the line U U′.

Let 1, 2, 3, 4, 5 be slits in the partitions at distances respectively one-fifth of v, two-fifths,

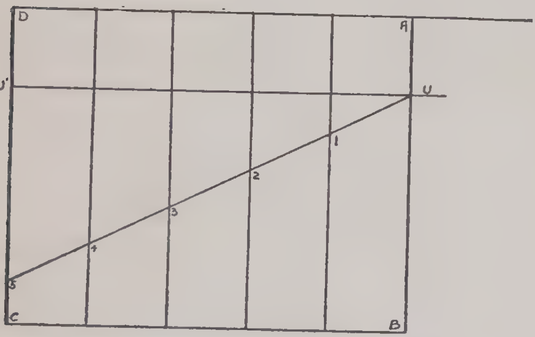

Fig. 9. Einstein's Box for light in a Galilean field

etc., etc., below the line of U U′. These slits will all be in a straight line. From the motion of the box the first slit will reach U U′ in one-fifth of a second, at the same time that the front of the light beam reaches the partition. The second slit will reach the line U U′ in two-fifths of a second at the same time that the beam front reaches the second partition, and so each slit in the line 1—5, reaches the line of the light's path just in time to meet the front of the beam. To the man in the box the ray of light passes obliquely across the box and in a *straight line.*

Second. Let the box be *accelerated* "upward."

Suppose the box to be divided by vertical partitions as in former case. Let a beam of light be sent across the box in a line at right angles to the sides of the box in the line U U′,

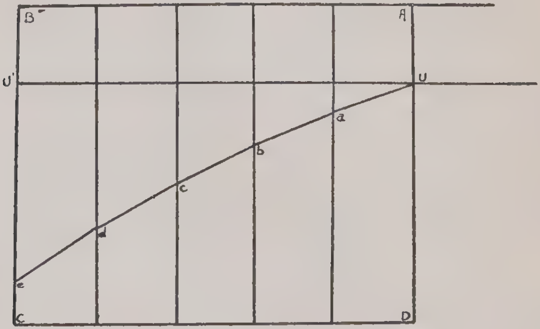

Fig. 10. Einstein's Box for light in an accelerated field

Suppose the box to have an accelerating g = 900 feet per second, as it would have if moving near the sun toward it. Let slits be made in the partitions at points a, b, c, d, e, such that the distance from a to the line U U′ is the distance the box will travel in one-fifth of a second; the distance from *b* to the line U U′ is two times a's distance from U U′ plus one-fifth of g; the distance from c to that line is three times a's distance plus two times one-fifth of g, and a like increase for d and e. These points, a, b, c, d, e, are not in a straight line, but curve downward. Each of these points will reach U U′ in the right time to meet the front of the light beam. The man in the box seeing the light beam passing through the curved line believes the light ray to be curved. Relativity adopts his view and says the path of the light is curved. It is evident that this is no proof at all that the path is curved in an accelerated field, or, as Einstein calls it, a gravitational field. The light in this box is not in a true sense in a gravitational field. Einstein in explaining the box experiment, does not allow any body which is not attached to the box to be accelerated. As the light is not attached to the box it is not accelerated or affected by "gravitation," and the box will catch up with it, as we have explained.

Third. *Light from a star as it passes the sun.*

This is the test which aroused the popular and scientific interest. It differs from the two preceding illustrations in that light passes here through a *real,* and not a fictitious gravitational field. If a particle of matter such as a meteoric stone be aimed so as to pass with velocity of light close to the disc of the sun, if not dissipated by the sun's heat, it would be attracted into a flat hyperbola, the two branches making an angle with each other of 0.87 seconds of arc.

If the "mass of the electro-magnetic energy of light" is subject to gravitation it will be attracted into a similar hyperbola and the light will be bent by 0.87 seconds of arc and its velocity decreased. But Einstein introduced a gravitational field by simply transforming co-ordinates in the manner approved by his general relativity. His result comes out such that it calls for a bending of the rays of light by an amount double that required by Newton's law of attraction. This result might be construed as merely superimposing an amount just equal to the Newtonian deflection upon it or as assuming that Einstein believes the entire bending is by a geometrical gravitational field. Most persons suspect a physical effect which is obtained simply by manipulating coefficients, and if a bend greater than that demanded by Newton and Maxwell is found they ask that other possible causes be first examined, such as refractions.

Fourth. *When Einstein Invents a Real Gravitational Field.*

We are disposed to believe in a bending of a ray of light in accordance with Newton's law of attraction; indeed we would accept a bending according to any proved law of *force* as we understand force. We are reluctant to allow "a geometrical force introduced by choice of co-ordinates" to bend anything, even light. Even Einstein seems to be awaking to the fact that many people prefer facts to fancies. In his lecture on what he calls his "ether" he quotes with approval Mack's "plotting into mechanics an average acceleration in proportion to the totality of the masses of the world." Then he says: "According to General Relativity the measurable qualities of the space-time continuum are different in the neighborhood of the individual space-time points and conditioned by the matter existing outside of the domain observed."

Einstein says again: "According to the general theory of relativity, the geometrical properties of space are not independent, but they are determined by matter. Thus we can draw conclusions about the geometrical structure of the universe only if we base our considerations on the state of the matter as being something that is known."

Since the amount and distribution of matter in the universe is not known, then Einstein's geometrical equations are brought in question. And our hope that Einstein's assumed bending of the ray of light might have a rational basis seems to be disappointed.

CHAPTER XVI

EINSTEIN'S ETHER

It is a common indictment of General Relativity that it denies the existence of an ether. Many condemn the entire theory on that ground. Some of its ablest adherents labor strenuously to show that it is not necessarily inconsistent with an ether. If those who demand that any theory of nature must include in its scheme an ether, be asked what kind of ether they want, they would perhaps find an answer not so easy. They might even question in their own mind why they need an ether at all, and begin to trace back to find the original of the concept. They would perhaps find that it arose from dissatisfaction with the theory of action of forces at a distance. The forces with which they were familiar were forces between bodies in contact. Therefore it is inconceivable that bodies as distant as planet from planet should send their forces across empty space. It was, however, answered that what they called contact was not in fact contact, but only action between molecules at a short distance. Then it was shown that light has many of the properties of a kind of wave motion, and we cannot have wave motion without something to wave. So they filled all space, even to the intermolecular spaces, with a medium. On account of what it is to do for light it was called the luminiferous ether. The history of the theories which have been devised as to the character and mode of action of the assumed medium is beyond our present plans.

We are at present concerned with the question of what kind of ether, if any, does General Relativity admit. Einstein himself is the proper one to ask for an opinion and pronouncement. In his lecture in May, 1920, on the subject of "Ether and the Theory of Relativity," he explained at length his theory of the ether, explaining the contrast between his theory and that of Lorentz and Maxwell. Also he gives some hints as to the connection of his ether with his theory of gravitation.

EINSTEIN'S ETHER IS SPACE EQUIPPED WITH PHYSICAL QUALITY

He says: "According to the theory of General Relativity, space is equipped with physical qualities. In this sense an ether exists. According to the theory of general relativity a space without ether is unimaginable, for in such an one there would not only be no *transmissibility of light,* but also no possibility of existence of measuring rods and watches, therefore no space time intervals in the sense of physics. This ether must not be thought of as equipped with qualities characteristic of ponderable media. The idea of motion must not be applied to it."

Again he says: "An important argument can be brought forward in favor of the ether hypothesis. To deny the ether means finally to assume that no kind of physical qualities belong to *empty space.* The fundamental facts of mechanics do not allow of this view." "We can assume the existence of an ether, only we must fail to ascribe to it a definite state of motion. We must take from it by abstraction the last mechanical mark which Lorentz has still left to it." Again, to emphasize the importance of not attributing mobility to his ether, he says: "We must be on our guard against imputing a state of motion to the ether."

1. Having read Einstein's definition of ether we are so perplexed that we read it over again. Surely there must be some hidden meaning in the German that cannot be translated. What we translate space must be a mistranslation. But

the German word is Raum which we are disposed to translate "Room." If asked to say what we mean by space many of us would be as well satisfied with Room as any other word—a place to put things—a place to put a medium. Einstein says: "According to the theory of general relativity a space without ether is unimaginable, for in such an one there would not only be no transmissibility of light, but also no possibility of existence of measuring rods and clocks, and therefore no space-time interval in the sense of physics."

By Einstein's own analysis of the origin of the ether notion, it came from two causes, 1st, Repugnance to the theory of action at a distance. 2nd, An effort to find some medium to transmit light and electric vibrations. Hence they filled all space with a medium. Now Einstein fills all *space* with *space*, but to conciliate us he calls physical space ether.

Sir Oliver Lodge characterizes this kind of reasoning thus: "The ether does exist or it does not. To attribute a property of wave transmission to a mere abstract geometrical space with nothing in it and no specifiable properties, is to stultify ourselves."

2. Einstein must make Arago, Brace and Michelson feel very simple. As Slosson expresses it in classic language: "They were like a blind-

folded man in a dark cellar trying to catch a black cat that isn't there." There is no such ether as they were looking for. Ether is just another name for "particles" of space. "The idea of motion must not be applied to it. We must be on our guard against imputing a state of motion to the ether." How foolish it was to spend time in trying to prove that particles of space do not move.

EINSTEIN'S "PHYSICAL PROPERTIES" OF SPACE

Einstein postulates that each point in space at a definite time is endowed with certain physical properties. And that the same point at a different time is endowed with different physical qualities. The fact that each different point in space has physical qualities peculiar to itself, he expresses by calling space "non-isotropic" or "non-homogeneous." We are so accustomed to meet here and there in nature with unsolved mysteries, that we would be willing to let Einstein have his guess at the riddle. We would not ask him how he found out that space is "non-isotropic," much less would we ask what made it so. But he volunteers the explanation and it is best told in his own words: "According to this theory of the ether the measurable qualities of the space-time continuum are different in the neighborhood of the individual space-time points, and conditioned by *the matter existing outside of the domain observed.* This space-time variability of the relations of measuring rods and watches to one another, and the fact that "empty space" in its physical qualities is not homogeneous, has set aside the view that space is physically empty. With this has come a concept of the ether far different from the ether of the mechanical undulatory theory of light. The ether of the theory of general relativity is a medium free from all mechanical and kinematical qualities."

"The principal difference between the ether of general relativity and the Lorentz ether consists in the fact that the status of general relativity ether is determined at every place by necessary connections with matter and with the status of the ether in nearby places in the form of *"differential equations."*

1. He says: "This ether is far different from the ether of the undulatory theory of light." It certainly is different from any imaginable ether. All other ethers are media in space. This has no medium in space. How light is transmitted he does not say.

2. What is meant by "conditioned by matter outside of the domain" of the "particle" of space is not explained, nor how it affects measur-

ing rods and clocks. It seems, however, that in some mysterious way "at every place the status of these particles of space" surnamed ether—"is determined by connection with matter and other particles of space by differential equations." It is very gratifying to at last find out what ether is and how it is connected with matter. That it is connected to matter by *differential equations,* and is physical space.

EINSTEIN'S ETHER AND ELECTRO-MAGNETIC THEORY

Einstein postulates his ether as absolutely necessary for the transmission of light. Then he completely discards transmission of light as a function of his ether. Does not suggest his ether as a conveyor or source of light and, of course, gives no theory of the transmission of light. His ether is wholly a "particle" of space with so-called physical qualities, or part of a gravitational field. He devotes considerable space to Maxwell's electro-magnetic theory and to a contrast between his ether and the electro-magnetic structure. He says: "The development of the theory of electricity by Maxwell and Lorentz made a marked change in the concept of the ether. For Maxwell the ether was a structure with purely mechanical qualities though much more complicated than those of solid bodies." He draws a sharp distinction between his ether and Maxwell's electro-magnetic field. In his ether no part of space is without gravitational potential which gives it its measurable qualities. Without gravitation space cannot exist.

On the other hand a "particle" of space can be imagined as without an electro-magnetic field.

Then he completely strips from an electro-magnetic field its claims to be an ether and calls it uncondensed matter. Or, perhaps better, makes all matter condensed electro-magnetic. He says: "Since, according to the present view, the elemental particles of matter are nothing other than condensations of the electro-magnetic fields, so our present picture of the world recognizes two perfectly separate realities—namely, the *ether* of *gravitation* and *electro-magnetic fields* or *space* and *matter.*

"It would be a great advance if we can succeed in interpreting the gravitational field and the electro-magnetic field as a unified structure. Then the contrast *ether* and *matter* would die away." This is, perhaps, a too brief or too long account of Einstein's so-called ether. To sum up, we note:

1. He starts out with the most vigorous denial that General Relativity can tolerate an

etherless universe. "A space without ether is unimaginable."

2. We had high hopes that, at last, we had an understandable, efficient medium in space which will do for us what an ether is expected to do with light, electricity, and perhaps gravitation.

3. To our disappointment we are told that the name "ether" is simply a camouflage for space or Raum. That every "particle" of space is endowed with physical qualities impressed upon it in some way by the matter outside of its domain.

4. This physical particle of space is surrounded by a gravitational field.

5. The transmission of light which was given as one of the urgent demands is not mentioned as a part of the work of the ether.

6. Einstein crushes our hope of having at least a kind of auxilliary to his "ether." Electromagnetic fields or lines are just uncondensed substance which some people call matter. They are not connected with any medium. There is no necessity for a medium.

7. Einstein wholly misrepresents Newton's belief in the necessity for an ether. Einstein says: "In order to be able to look upon the rotation of a system, at least formally, as something real, Newton objectivates space. By calculating his absolute space as something real for him Newton

could have named his absolute space just as well 'ether.' It is only essential that another non-perceptible thing must be looked upon as real in order to be able to look upon the acceleration or rotation as something real." Certainly, Newton believed that the earth rotates, if Einstein does not. Newton "objectivates" space for he doesn't know any other place to put the earth, the sun and stars, unless he can get "room" for them some place. But unlike Einstein he believed in an ether in space.

Again, Einstein says: "Only by Newton's theory of gravity was a cause for gravity determined, being interpreted as a distant force which originates from masses. This theory produced keen discomfort among Newton's contemporaries because it seemed to contradict the principle from former experience that there is only reciprocal action by contact and not by immediate action at a distance."

Pity that Einstein had not read what Newton did say. He says: "It is inconceivable that brute matter, should, without the medium of something else which is not material, operate on and affect other matter without material contact as it must do if gravity in the sense of Epicurus be essentially inherent in it. That gravitation should be innate, inherent and essential to matter so that one body may act upon another at a distance through a *vacuum* without the mediation of anything else by and through which their action or force may be conveyed from one to the other, is to me so great an absurdity that I believe no man who has in philosophical matters a competent faculty of thinking can ever fall into it."

We almost wish that Einstein had not delivered that lecture. It is not alone that we are disappointed that what started out with such promise got us no where, but the worst is our disappointment with Einstein.

CHAPTER XVII

MASS OF BODIES CHANGES WITH THEIR VELOCITY

Conservation of mass has been a fundamental concept. A few years ago it was announced that certain experiments on cathode rays and radium effluves had shown that certain small bodies increase their mass when moving with high velocity. We received the announcement with either incredulity or concern. Are all our fundamental concepts to be undermined? When relativity found that somebody had discovered a strange thing, it added it also to its collection.

What is meant by *Mass* of a body?

Mass has been commonly defined as the quantity of *matter* that the body contains. That definition will be criticised. So would any other definition be, so we may just let it stand. Then we may be challenged to define matter. In order to make a sensible definition of anything we generally try to define it in terms of some more fundamental or better known object. We cannot do that for matter. If we call it "energy" or "condensed electro-magnetic lines," or just plain matter, we know about what is meant.

If mass of a body is the quantity of matter it contains, we cannot see how the mass of a body can grow greater unless it has more matter added to it. But we find in Relativity two masses of the same body called for, mass of the body at rest and mass of the body in motion. Also, in addition, two principal masses of the same body in motion are demanded, one its *transverse* mass, that is, its mass in a direction perpendicular to its line of motion; the other its *longitudinal* mass, that is, its mass in a direction parallel to its line of motion.

TWO WAYS OF PROVING THAT MASS INCREASES WITH VELOCITY

(1) By Experiment. (2) By Relativity.

(1) By experiment and observation.

Radio-active bodies constantly send out "effluves" normally and all other bodies likewise when subjected to certain stimuli, such as the action of ultra-violet light impulse. But if the mass of the body sending out its emanations changes it is because it has lost matter. If a gramme of radium C′ reduces its mass by one-half in one ten-billionth of a second, or a gramme of thorium reduces to one-half in twenty-six billion years, if these effluves could be gathered up and returned, the mass would be unchanged we naturally say. Le Bon would say, they cannot be returned because this radio-action is a process of dematerializing of matter. These Beta rays are passing into an "intermediate world between ether and matter." Still the mass of the original has not been changed because of its motion. The experimenters ought to say the effluves could not return and restore the mass because their mass has been increased by their speed and the restored mass would be greater. They ought to say it if consistent, but I doubt if they have thought of such a crucial test.

EXPERIMENTS TO PROVE THAT THE MASS OF ELECTRONS CHANGES WITH CHANGE OF VELOCITY

It has long been known that an electric current has inertia. Inertia of a body is a measure of its mass.

Without stickling over names we may take this concept of bodies: "All bodies are composed of small particles called *atoms*, together with smaller ones called *electrons*."

The electron is often called atom of electricity as distinguished from the atom of matter. The atom of electricity was called electron long before anything was known of its mass or its various rates of motion. J. J. Thompson, in 1898, was able to measure the mass of the electrons that are sent out from the cathode or negative pole of an induction coil. He sent the cathode rays directly through a vacuum tube and had them fall on a properly prepared plate. He saw now that the rays were moving in straight lines.

It was known that if an electric charge moves rapidly past the end of a magnet the charge is deflected sidewise. If these rays are "atoms" of electricity they will be deflected by a magnet. Thompson placed a magnet of known strength at right angles to the line of motion of the cathode rays. He found that the rays were bent into circular trajectories whose radii could be measured. By introducing an electric field at the same time, the effect was to separate the speed effect from the mass effect. He found that the mass of an electron is about one two-thousandth of the mass of a hydrogen atom, and moved at rate of one-tenth that of light.

These experiments led the way to experiments which are held to show that the mass of rapidly moving bodies is increased with increase of velocity. When radium and other radio-active substances were found to be sending out "effluves" it was to be expected that the same method which had been successfully tried on the cathode rays should be tried on these rays. If they are moving electrically charged bodies they may be deflected from their straight path by attraction of a magnet. When the experiment was tried three classes of rays were discovered. Two sets of rays were deflected, but in opposite directions; one class not deflected by any amount detectable by any means they had. They found that about nine-tenths of the total rays were deflected into circular trajectories of comparatively short radius, yielding on computation a velocity of one-tenth that of light, and having a mass of four times that of hydrogen atoms, as they were shown by Rutherford to be the gas helium. These are called the Alpha rays.

The remaining atomic rays, called Beta rays, were deflected into circular trajectories of different radii. From each trajectory a velocity and mass were computed. The velocities ranged from six-tenths to nine-tenths that of light.

Kaufman and Abraham, who made the first tests, subjected the Beta rays to the joint action of a magnetic and electrical field. The magnet drew the electric charge e aside into one plane, and the electric field drew the mass m into a plane at right angles to the first plane, not separating *e* and m of course. Knowing the relative magnetic and electric intensity and observing the relative deflection under the two fields, they could calculate the ratio of e to m. They found this ratio to vary with the velocity. The greater the velocity the smaller the fraction e divided by m. As they assumed that the charge e was a constant or of the same value throughout, therefore mass increased with velocity. Abraham, from his empirical formula found the mass of an electron with velocity one-fifth that of light has increased only one-eightieth; for velocity of one-half that of light mass has increased one-tenth; for velocity three-fourths light, increase is one-third; for velocity nine-tenths light mass has increased eight-tenths. For velocity greater than nine-tenths that of light they had to depend on the result of computation, as no observations of greater velocity were available.

In comment we may say:

(1) We do not see here any source from which new substance entered the electron, and if we adhere to our definition of mass—the quantity of substance in a body—how does this mass increase?

(2) It is assumed that e does not differ. Why do different electrons issue from atoms and move

with different velocities? May not the fact that they do differ show that they are intrinsically different? The ether of which each is composed rotates at a different rate. Different electrons flatten in a different way and offer different fronts to the resisting ether.

(3) The increased inertial mass may be only apparent, but due to the increased resistance to larger velocity. Suppose, as a rough illustration, that a gallon of water be enclosed in a bag of the same specific gravity as the water. Suppose its normal inertial mass be measured by the force necessary to haul it at a uniform rate along a perfectly smooth surface in a vacuum. Now this bag is hauled horizontally through still water of the same specific gravity as that in the bag. The greater the uniform rate of motion we give to the bag the greater the resistance or the greater the apparent mass.

In the same way the electron "bag" of ether encounters greater resistance from the ether through which it is moving the greater the velocity, and hence the mass appears to be greater. Whether conclusions from experiment are convincing or not makes little difference to relativity, so we turn to see how Relativity proves the proposition.

MASS INCREASED BY VELOCITY ACCORDING TO RELATIVITY

A concrete illustration of Relativity's explanation of increase of mass from increase of velocity is given by Lewis and Tolman and quoted with approval by Carmichael.

Suppose two systems of reference S and S′ moving with relative velocity V. "An experimenter A on the system S constructs a ball B of some rigid elastic material, with unit volume, and puts it in motion with unit velocity in a direction perpendicular to the line of relative motion of S and S′, the units of measurement being those belonging to S. An experimenter C on S′ constructs a ball B′ of the same material of unit volume and puts it in motion with unit velocity in a direction at right angles to the line of relative motion of S and S′. Assume that the experiment had been so planned that the balls collide and rebound over their original paths, the path of each ball being thought of as relative to the system to which it belongs."

After collision with the ball, B′ will go back over its original path with momentum M W, W being the velocity of the ball and M its mass. Now the distance the ball goes back divided by the time of motion is its velocity W.

A is watching the motion of B′. He has been taught by relativity that the time unit on S′ is longer than his own in the ratio of $1 : \sqrt{1 - \frac{v^2}{c^2}}$. Hence he concludes that, since the distance passed over by B′ is the same as the distance passed over by B, and B′s time is longer, therefore the velocity of B′ is smaller than the velocity of B. Now since M W is constant and W smaller, A concludes that M is larger and has been increased in ratio of $1 : \sqrt{1 - \frac{v^2}{c^2}}$.

A, having found, to his satisfaction, that B′ has increased its mass by moving in a line perpendicular to the line of relative motion of S and S′, is interested to know whether his ball has changed its mass. He has no way of testing it directly, so he takes it over on S′ and puts it beside B′. B and B′ are just alike as two peas. Hence he concludes that his ball B also would change its mass in the same ratio when it is moving at right angles to the line of relative motion of S and S′.

On the strength of this illustration, Carmichael enunciates for relativity thus:

Theorem: "Let M denote the mass of a body when at rest relative to a system S. When it is moving with velocity V relative to S, its transverse mass, that is its mass in a direction perpendicular to its line of motion, call M′ its mass,

Then $M' = M_0 \left(1 - \frac{v^2}{c^2}\right)^{-\frac{1}{2}}$.

In comment it may be said:

(1) The "proof" is based upon the assumed fact that the time units are different on the two systems. That the time units differ is assumed on hearsay evidence, which we have shown to be unreliable.

(2) In this proof it is assumed that the *time* unit only appears longer on one system than on the other. Whereas in fact the *distance* increased in the same ratio. If the distance in the numerator and the time in the denominator are multiplied by the same factor, the value of the fraction is unchanged, and if W is unchanged M W is unchanged, therefore M is unchanged.

(3) The naïveté of A's proof that his ball increases its mass is charming. He watches C's ball and concludes that its mass is increased by its motion. He takes his ball over and puts it beside C's ball. He cannot detect the slightest difference. Therefore he concludes that his ball has just as good right to increase its mass as has C's, therefore his ball's mass will become B $\left(1 - \frac{v^2}{c^2}\right)^{-\frac{1}{2}}$ when in motion V at right angles to the line of motion of the system.

A and C have two sorrel horses exactly alike. In the twilight A thinks C's horse is black. His neighbor also tells him that C's horse is black. A takes his horse over and puts him beside C's horse; they are exactly alike, so A agrees that his horse is black.

(4) This is by-play. But we are disappointed when able and astute men make a theorem of realities out of them. Let A say his sorrel horse is black, but don't insist on everyone being color blind.

LONGITUDINAL MASS

Relativity "proves" that when a body is moving with a velocity V relative to a system of reference S, its longitudinal mass, that is its mass in a direction parallel to its line of motion = $M_0 \left(1 - \frac{V^2}{C^2}\right)^{-3/2}$".

COMPARISON OF THE RESULTS OBTAINED FOR INCREASE OF MASS OF A MOVING BODY, BY USE OF RELATIVITY'S FORMULA, WITH RESULTS OBTAINED BY ABRAHAM'S EMPIRICAL FORMULA BASED ON ACTUAL EXPERIMENT

It may be said that they do not differ very largely. But that agreement gives no proof of relativity. This factor $\left(1 - \frac{V^2}{C^2}\right)^{1/2}$ is the factor devised by Lorentz to account for the apparent failure of the Michelson-Morley experiment. It was based on his theory that electrons actually changed shape when in motion. Relativity's discussion is invented to get into the expression for mass what Lorentz had already got into it.

CHAPTER XVIII

EXPLAINS UNEXPLAINED PHENOMENA

If a theory explains hitherto unexplained phenomena it begins to claim our confidence. If it predicts events, and its predictions are verified, it becomes still more firmly fixed in our belief. Popular, as well as scientific interest, was aroused by Einstein's claim that he had invented a theory by which he explained and predicted three interesting phenomena.

1. His theory professed to explain a long standing mystery in the motion of the major axis of Mercury's orbit.

2. It predicted a certain deflection of light as it passes through a gravitational field such as exists around the sun.

3. It predicted a slowing of the vibrations of the atoms of the sun's atmosphere by the sun's gravitation, and that this slowing may be detected by the spectroscope.

1. EINSTEIN ACCOUNTS FOR THE REVOLUTION OF THE MAJOR AXIS OF MERCURY'S ORBIT

According to Newton's law of gravitation and his laws of motion, if the only bodies in the universe were the sun and Mercury revolving around him, Mercury would describe an eclipse of uniform size, shape and position in space. But every planet exerts its effect to disturb Mercury's motion in its orbit. Each planet exerts both its direct and indirect pull upon Mercury. Jupiter's pull is different because Saturn has pulled both Jupiter and the sun. The perturbative effect of each planet directly, and indirectly because it has been pulled by every other planet in the solar system, makes a tangle of gravitational influence which taxes the mathematical ingenuity and skill of the ablest mathematicians. The size, shape, motion and position were calculated first by Leverrier and later by two of the ablest mathematical astronomers, Newcomb and G. W. Hill.

In 1858, Leverrier made a careful collection of all observations of the transit of Mercury over the sun's disc, since the invention of the telescope. He was not able to reconcile the results of observations with the computed motions of the planet. He found, however, that if he assumed a motion of the perihelion of the orbit at the rate of thirty-six seconds of arc in a century, the computed and observed positions would agree. G. W. Hill's computed motion is at the rate of forty-three seconds in a century, to make observed and computed positions agree.

This outstanding progressive motion of the major axis of Mercury's orbit is what Einstein's General Relativity claims to have explained. By developing the "equation of motion of a particle in a gravitational field" a final result is reached that *while the planet moves through one revolution, the perihelion advances a fraction of a revolution equal to* $\frac{24\,\pi^3 a^2}{T^2 C^2\,(1 - e^2)}$ where T = the period of revolution, a = the semi-major axis, e = the eccentricity of the orbit and c = the speed of light. Substituting in this expression the values of these terms for Mercury, the result is forty-three seconds of arc in a century, which is what is needed to make computation agree with observation.

In comment it may be said:

(1) Einstein's equations from which his results are reached, involve at the outstart, unproved and doubtful assumptions and, of course, the outcome is tainted with the same faults.

2. Even in the manipulation of his equations, terms are thrown away because he pronounces them negligibly small. Some of these involve the

Lorentz contraction value which was brought in with such glee. The history of astronomy has a long list of radical errors in result due to omitting higher powers from equations. The deceived ones may surely rank with Einstein in mathematical acumen, such as Newton, Leverrier and Laplace.

3. As a proof that even able relativists do not consider Einstein infallible, Eddington entirely reverses Einstein's explanation of his rotating disc. Einstein says: "If the observer applies his standard measuring rod tangentially to the edge of the disc, the length will be less than one, since moving bodies suffer a shortening in the direction of motion. On the other hand it will not experience a shortening in length if it is applied to the disc in the direction of the radius." Eddington says: "We may say that our measuring rod contracts when *placed radially;* transverse measures require no correction." Einstein's own equations require the radial contraction which he denies. Pity that Eddington could not agree with Einstein and he contract the radius while Einstein contracts the circumference, and still preserve some symmetry in the curve.

But Eddington, now fairly started, proceeds to wreck Einstein's entire outfit of poor clocks and elastic rods and snail platforms, and charges the whole trouble to Euclid. It would give us an imperfect understanding of Eddington's theory if only a condensed quotation be given. So I shall quote him at some length. In commenting on the Einstein assumptions, he says:

"But there is more than one way of correcting the measures to fit Euclidean space, so that we are really not justified in making precise statements as to the behaviour of our clocks and measuring rods. It is better not to discuss their defects, but to accept the measures and examine the properties of the non-Eculidean space and time. If we draw a circle with a heavy particle near the center, the ratio of the measured circumference to the measured diameter will be a little less than π, owing to the factor $\frac{1}{\gamma}$ affecting the radial measures. It is thus like a circle drawn on a sphere, for which the circumference is less than π times the diameter if we measure along the surface of the sphere for the diameter. We may imagine space pervaded by a gravitational field to have a curvature in some purely mathematical fifth dimension. If we *draw the elliptic orbit of a planet, slit it along the radius and try to fold it around our curved space* there will evidently be some overlap. For example, take a cone with the sun as apex as roughly

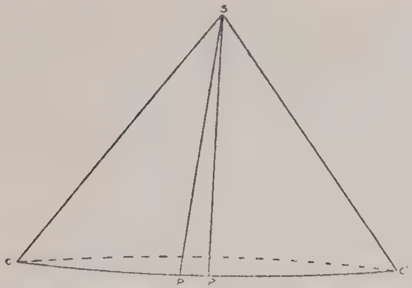

Fig. 11. Overthrowing Euclid by calling a cone a circle

representing the curved space. Starting with the radius vector S P, the Euclidean space will fold completely around the cone and overlap to the extent P S P′ each revolution." (See Figure 11.)

This shows one reason for the advance of perihelion of a planet, which is one of the most important effects predicted by the new theory."

Answering the suspicion that there is an admixture of metaphysics in a theory which reduces a gravitational field to a modification of the measurable qualities of space and time, he says: "There is nothing metaphysical in the statement that under certain circumstances the measured circumference of a circle is less than π times the diameter. The trouble is that we have inherited a preconceived idea of the way in which measures, if true, ought to fit. But the relativity standpoint is that we do not know and do not care, whether the measures under discussion are true or not." In comment we may say:

First. We acquit the theory, as thus explained, of being metaphysical. We have a high opinion of sane metaphysics and metaphysicians. Second. The explanation is highly Einsteinian in that it starts out professing to discard contracted measures and then builds the whole explanation on the theory that the circumference contracts; also starts out to discuss circles and then bases his statement on cones and segments of spheres. Third. Rather than "slit the elliptic orbit of Mercury along a radius vector and wrap it round curved space" to see how much it overlaps we shall hope on, that some relief to the astronomical mind may come from one of the following cures for Mercury's trouble, most of them old it is true.

(a) A new computation of Mercury's motion and orbit using probably better planet masses and more extended and better equations. It is true that the outlook for relief from this direction is not encouraging. The names of those men who have made the computations in the past would give little hope that much improvement on their work is possible. But illustrious names have not deterred other able men from following them and detecting their errors. Even "Great Homer nods." The task is appalling; it means years of work and large expenditure of money. And worst of all, the number of men in the world who could do it is very small indeed. Unless Einstein could be induced to do it. Most people perhaps think he did it.

(b) The attraction of hitherto undiscovered bodies between the sun and Mercury. The history of the search for such bodies is interesting but disheartening. Vulcan (as the mythical planet was named) seen by observers, as it projected itself on the sun's face in transit, turns out to be a sun spot. Even two "Vulcans" seen near the sun at time of an eclipse prove to be stars. Until now it is confidently announced that no planet large enough to be seen is between the sun and Mercury. We all remember the announcement in text books not so old, "Mars has no satellite."

But not all are agreed that because no large planet is revolving between the sun and Mercury, that therefore there is not enough undetected matter in that region to cause the observed result. Newcomb says "The smaller we suppose the individual planets, the more numerous they must be. The smaller and more numerous they are, supposing their combined mass the same, the greater the sum total of light they would reflect. At a certain point the amount of light would become so considerable that the group would appear as a cloud-like mass. Now, there is a phenomenon known as the Zodiacal light which is probably caused by matter either in a gaseous state or composed of small particles revolving round the sun at various distances from it. This light can be seen rising like a pillar from the western horizon on any very clear night in the winter or spring. Of its nature scarcely anything is known. We can therefore merely suggest the possibility that the observed motion of the perihelion of Mercury is produced by the attraction of its mass." Of the same character of surmise is the hypothesis that a meteor swarm has its node near the orbit of Mercury.

(c) In 1885, when Einstein was six years old, that brilliant worker on planetry orbits, Newcomb, wrote: "An electro-dynamic theory of gravitation has been, within the past twenty years, suggested by several German physicists, which involves a small variation from the ordinary theory of gravitation. It has been shown that supposing this theory true, the motion of the perihelion of Mercury could be accounted for by the attraction of the sun." When Newcomb says "it has been shown" that the effect is accounted for without relativity, without slitting an ellipse, without calling a cone a circle, it means much.

II. TEST OF EINSTEIN'S PREDICTION OF THE DEFLECTION OF LIGHT BY THE SUN

Einstein, in his paper published in 1905, announced the theory that light is subject to gravitation. That in passing near a body which is surrounded by a gravitational field light may be deviated from a straight line. The bending of a ray of light is always caused by its passing through the gravitational field surrounding any body, but on account of the great velocity of light and the small deflecting power of gravitation, in case of the planets, the deviation cannot be detected by our present means of measurement. A ray of light—as the light from a star—which passes close by the disc of the sun, on its way to reach us, will be deviated an amount which is measurable. The amount of that deviation was computed by him at that time, and by others, on two hypotheses. 1st. The hyperbola which a heavy particle would describe if it has the velocity of light and passing near the surface of the sun, is attracted by the sun according to Newton's law of attraction, was computed. It was found that the two branches of the curve for a particle just "grazing" the disc would make an angle with each other of 0.87 seconds of arc. For stars passing the sun at greater distances the deviation varied inversely as the distance from the center of the sun.

2nd. On the theory that light consists of electro-magnetic energy and is subject to gravitation as it passes the sun, the curve was computed, the result being the same amount of deviation.

In 1915, Einstein had invented his "General Relativity," which brought into action his curved space-time hypothesis. This new manipulation of equations brought out a result just double the amount of deviation which Einstein had predicted ten years before, that is, a deflection of 1.74 seconds of arc for a ray passing close to the sun; with a decrease in the inverse ratio of the distance from the sun's center for rays passing at greater distance from the sun. He declared that eclipses of the sun would verify his prediction. We admire the courage of a man of science when he challenges all astronomers that he will stand or fall by the test which they themselves may make.

The experiment consists in photographing the stars which are at the time apparently close to the sun, so that their light passes near his edge as it comes to us. Then photographing the same stars at night when the sun was not near them. The difference between the photographed positions of each star was assumed to be due to the deflecting influence of the sun on the light of that star. This observed deflection for each star is now compared with the deflection which each theory, Newton's and Einstein's, demands for a star passing at that distance from the sun's edge.

This experiment can only be made, at present, when the sun is eclipsed, as when the sun's light is not shut off by the moon it blots out the light of the star.

The experiment has been tried at least twice.

First. On June 8th, 1918, Professor Campbell, during the solar eclipse, made a test at Goldendale, Washington. The conditions were rather unfavorable, for the only stars near the sun were ninth magnitude stars, and the nearest star to the disc of the sun was about twice the distance of the sun's radius.

"The result from all the observations was a mean displacement of 0.05 seconds of arc in the right direction." The computed displacement from Newton's law for these stars was 0.08 seconds of arc and from Einstein's theory 0.15 seconds of arc. The deviation was almost negligible —not much more than half what Newton's law would involve and only one-third of Einstein's prediction.

Second. A fairer test was made at time of the sun's eclipse May 29th, 1919. Two well equipped British expeditions composed of able astronomers photographed the stars near the sun at stations, one at Sabral, Brazil, the other on the Isle of Principe, west coast of Africa. At the time of the eclipse the sun was near a field of bright stars, the Hyades. One of the parties stayed long enough after the eclipse to photograph the same stars at night more than once. When the photographic plates were measured and the undeviated night positions compared with the eclipse plates, it was announced that the deviations were nearly what Einstein had predicted. The announced result was hailed with enthusiasm and almost hysterical excitement. Even Sir Joseph Thomson in making the announcement, said: "It is the result of the highest achievement of human thought. The weak point is the great difficulty in expressing it. It would seem that no one can understand the new law of gravity without a thorough knowledge of the theory of invariants and the Calculus of variations."

Certainly this pronouncement ought to command attention, for it is made by one of the highest authority, if he has examined the subject. Does the fact that the "theory of invariants and calculus of variations" has been used necessarily prove anything? The process in any legitimate research by mathematics proceeds in this way: 1st. Certain axioms, postulates or definitions are assumed. 2nd. These definitions and so forth are translated into equations. 3rd. These equations are transformed and manipulated according to the laws of the kind of mathematics which is being used, and guiding the manipulations toward the desired end. 4th. These resulting equations are then translated back again into a law or theory.

If the postulates were wrong or doubtful, no matter how learned may be the calculus, and how skillfully the "ponderous machinery" (so Lodge says) has been wielded, the end may be worse than the beginning. This test is by no means accepted as conclusive by many competent solar physicists.

The objections are aimed for the most part, rather at the explanation of the result of the test than at the theory.

Without seriously questioning the accuracy of the process by which the amount of the predicted deviation is deduced, we just mention two things in passing: 1st. An entirely wrong and too small "mass of electro-magnetic energy" is used in proving that if the "mass of electro-magnetic energy" is subject to gravity the deviation will be the same as for a material particle, and that this accounts for half the Einstein prediction from General Relativity.

2nd. When the final equation is evolved and we have Eddington's conclusion: "The course of the ray will be the same as in a Euclidean space filled with material of suitable refractive index. The gravitational field around a particle will act like a converging lens," we see visions of the untroubled age of the ancients far back of Ptolemy and Hipparchus, when crystalline spheres studded with star gems rolled about the fixed earth.

Accepting the announced results as to the deviations of the light of the stars, let us place the two assumptions over against each other, and let each advocate state his conclusion as if he has proved it. First. Einstein, "the results fully confirm my predictions." Second. Objector, "the results are due to one or all of the following causes: (a) The refraction of light as it passed through the gases surrounding the sun. (b) The variable refraction of the light as it passed through the air. (c) Distortion of the photographic apparatus.

(a) Refraction of the star light by the gases near the sun. Instead of seeking far for the reason for the light being deviated, we might be filled with wonder if the light were not refracted. The main proof that the moon has little, if any, atmosphere is the fact that the length of time a star occulted by the moon remains hidden is just the length of time it takes the moon to move a distance equal to its breadth. The star light is not refracted, therefore there is no atmosphere. Proctor has said: "If the moon had an atmosphere as thick as the earth atmosphere, a star behind the moon would not in a sense be hidden at all, but its light refracted all around it would make a crown of light encircling the moon."

That the rays of light from many, if not all, the test stars which were photographed passed through gases is clear. Dr. Bauer, who observed the eclipse at Cape Palmas, Liberia, declared that it was the "most magnificent one of the four he had seen. Not only was the corona beautifully developed, but also a striking crimson prominence appeared on the sun's southeast limb which shot up one hundred thousand miles and had a base of three hundred thousand miles."

Outbursts have been seen on the sun which sent out the gases hydrogen and helium with such velocity as suggest that some of it even passed beyond the sun's control. If the so-called prominences are still hot enough to be visible at one hundred thousand miles above the surface of the sun, there is no doubt that they extend much beyond that height in fact. Eddington said in his discussion of the result that the refractive index of the gases through which the light passed to produce the observed effects of this eclipse would have to be $\frac{1}{200}$ of gases. Hydrogen has a refractive index of 2 and helium of 1½

The corona through which the light came has a gas coronium whose refractive index we do not know.

(b) "How completely was it possible for the British observers to eliminate differential refraction effects as the rays passed through the earth's atmosphere?" Variable refraction is bad enough in astronomic work when the sun is down. Every "twinkle" of a star is caused by the jump of the starlight as it meets a new stratum of air with a different refractive index. Much more troublesome is the air on solar work. "Heat" currents in the instrument tubes, changing humidity of the air, water vapor in the air absorbs very strongly solar heat.

Height above the ground. Professor Hale found much improved work with an instrument mounted in a pine tree eighty feet above the ground. Whether the problem was solved by these observers or not, it was not an easy one. The water vapor when the full sunlight fell upon it was different when the chill fell on it as the moon covered the sun. The night work, whatever uncertainty it involved, had different conditions than the day work.

(c) Distortion of the apparatus. So sensitive to heat effect is a speculum that in fine work observations are made by a telescope so as to not affect the instrument by the heat of the body.

III. THE SPECTRAL LINES OF THE SUN WILL BE SHIFTED TOWARD THE RED END OF THE SOLAR SPECTRUM

This is regarded by Einstein and his followers as almost the supreme test of general relativity. In every phase of Einstein's discussion, relativity has been tested by its effect on rates of clocks. An atom of matter—as sodium—for instance, vibrating at a point in a gravitational field is a natural clock, and as such ought to be regulated by Einstein. Ever since spectroscopy has been invented, the time of vibration of one of the atoms of matter has been suggested, as a standard of time. Lord Kelvin said: "The ultimate standard of accurate chronometry must (if the human race lives on the earth for a few millions of years) be founded on the physical properties of some body of more constant character than the earth." Then he says: "The time of vibration of a sodium particle is known to be absolutely independent of its position in the universe, and it will probably remain the same as long as the particle itself exists."

Einstein on the contrary says: that an atom vibrating at a definite point in a gravitational field vibrates at a uniform rate all the time. But an identical atom at another point in the gravitational field—at which the gravitational influence is different—will, while vibrating uniformly, vibrate at a different rate from the rate of the first atom. Thus, if an atom of hydrogen is vibrating in the laboratory, and an identical atom is vibrating in the sun's atmosphere, the two times will be different because the gravitational fields are different.

It is computed that if $t =$ the period of vibration of an atom in the sun's atmosphere, and $t' =$ the period of vibration of an identical atom in the laboratory, then $t = 1.00000212\ t'$. The solar atom vibrates more slowly and its spectral line will be displaced toward the red end of the solar spectrum. The displacement ought to be just as if the atom were moving away from us at the rate of 0.422 miles a second. This amount of displacement could be detected in the spectroscope. It seems that the best evidence so far is that there is no such displacement, though there is not full agreement that it does not exist.

Relativists seem to give this test more weight than either of the others already discussed.

Eddington says: "The effect is of particular importance, because it has been claimed that the existence of this displacement is disproved by observations of the solar spectrum. The difficulties of the test are so great that we may perhaps suspend judgment. But it would be idle to deny the seriousness of this apparent breakdown of Einstein's theory." Again he says: "There is little chance of evading the conclusion that a displacement of the Fraunhofer lines is a necessary and fundamental condition for the acceptance of Einstein's theory: and that if it is really non-existent under conditions which accord strictly with those postulates, we should have to reject the whole theory constructed on the principle of equivalence. Possibly a compromise might be made by supposing that gravitation is an attribute only of matter in bulk and not of individual atoms. But this would involve a fundamental restatement of the whole theory." It surely would, for the main part of the theory is based on electron contraction, variation in mass of electrons with velocity, attraction of mass of electro-magnetism and like assumptions.

Einstein himself says in the appendix to his

"Relativity": "If the displacement of spectral lines toward the red by the gravitational potential does not exist, then the general theory of relativity will be untenable." What then will become of the "two very severe tests in connection with the perihelion of Mercury and the present eclipse"? What of the theory "too difficult to be expressed"? What of the theory which has been evolved from "a thorough knowledge of the theory of invariants and the calculus of variations"? What of the eleven apostles? Has disaster come from a disregard of Lord Kelvin's warning: "Nothing can be more fatal to progress than a too confident reliance on mathematical symbols: for the student is only too apt to take the easier course and consider the formula, and not the *fact* as the physical reality."

CHAPTER XIX

A BRIEF SUMMARY OF SOME POINTS THAT HAVE BEEN MADE IN OUR DISCUSSION

1. What has relativity done with the Michelson-Morley Experiment?

The whole riot started with this experiment. At first there was keen disappointment that the experiment had not solved the ether motion problem. Then came (a) Fitzgerald and Lorentz, who pronounced it an epoch-making success. First. It proved that the ether *is* at rest relatively to the earth's motion. The reason the experimenters and others who discussed it did not see that they had solved the problem was that they did not understand their apparatus.

Second. It proved the far more important fact that all bodies change shape when pointed in the direction in which the earth is moving.

Third. It was proved that if d represented the length of the body when lying at right angles to the line of motion, the length of the same body when pointing in the line of motion is $d\sqrt{\left(1-\frac{v^2}{c^2}\right)^{\frac{1}{2}}}$. Thus came in the famous Lorentz contraction coefficient.

(b) *Relativity* entered and adopted this Lorentz co-efficient. It might not be wide of the mark to say that if there never had been a Lorentz coefficient there never would have been an Einstein Relativity. There is not a phase of Einstein's Relativity proper that does not revolve about this coefficient.

Einstein says: "Lorentz and Fitzgerald rescued the theory from the difficulty by assuming that the motion of the body relative to the ether produces a contraction of the body in the direction of motion, the amount being just enough to compensate for the difference of time. This solution was the right one, but on the basis of the theory of relativity the method of interpretation is incomparably more satisfactory. The contraction of the bodies follows from the two fundamental principles of the theory without any introduction of particular hypotheses." Then again: "For a co-ordinate system moving with the earth the mirror system of Michelson and Morley is not shortened, but it *is* shortened for a co-ordinate system which is at rest relative to the sun."

We, I think, are rather disposed to believe that the apparatus either did shorten or it did not. And we are inclined to let Lorentz shorten it in a physical way rather than to let Einstein get somebody to shorten it by looking at it from another system.

Eddington, on the whole, adopts this coefficient more times than he disowns it. He says: "By experimenting at different times in the year the existence of the contraction has been fully demonstrated." Then a few pages farther on he says: "When a rod is started into uniform motion nothing whatever happens to the rod. We say that it contracts, but length is not a property of the rod: it is a relation between the rod and the observers." Again he says: "The Michelson-Morley experiment was necessarily confined to solids of laboratory size. There is no experimental proof that a body such as the earth, whose figure is determined mainly by gravity, will undergo the theoretical contraction owing to motion." After all this it is interesting to read: "If we transfer ourselves to Arcturus the contraction $\left(1 - \frac{v^2}{c^2}\right)^{1/2}$ must be different.

After declaring against a contraction, Eddington again elaborates its possibility in an interesting illustration. "Let us assign to the earth a velocity of one hundred and sixty thousand miles a second, say, in a vertical direction. With this speed $\left(1 - \frac{v^2}{c^2}\right)^{1/2} = 2$, and the contraction is one-half. A rod six feet long when horizontal contracts to three feet when placed vertically. Yet we never know the change. If the standard yard measure is brought to measure it, the rod will still be found to measure two yards. The standard yard experiences the same contraction when placed alongside and represents only half a yard. We do not perceive a change. What we see is an image of the rod on the retina. We think that the image occupies the same space of the retina in both positions; but our retina has contracted in the vertical direction without our knowing it, and our estimates of length in that direction are double what they should be." We are somewhat perplexed to decide whether the eye contracts the rod or whether Lorentz and Einstein did it. Our perplexity is not lessened when we turn back and read: "When a rod is set in uniform motion from rest nothing whatever happens to it." Eddington is a wonder in abstruse modern mathematics.

2. USES MADE OF THE LORENTZ COEFFICIENT

(a) In Einstein's Kinematics.

So-called Einstein transformations were not original with him. He showed that the value for time that had been introduced in the equations already invented and which was simply introduced for mathematical requirements, fitted into his relativity.

These equations of Einstein's have in them this Lorentz coefficient. And it is very useful in proving such valuable things as that ¾ c plus ¾ c equals c, that two equals one, and such like.

(b) In relativity's equation for moving mass.

Relativity ever on the alert to add to its startling collection found that Abraham had made an equation between the mass of a body at rest and a body in motion, and that an equation involving the Lorentz coefficient had also been devised. By a process of reasoning such as we have already given, in which two moving balls were used, relativity appropriated the Lorentz Mass. The value for mass obtained is $m' = m_0 \left(1 - \frac{v^2}{c^2}\right)^{-\frac{1}{2}}$ in which m' is the mass of the body in motion and m_0 its mass when at rest. This is valuable for sensational purposes, for when $v = c$, the mass of the moving body is infinite. But Abraham beat them to it in his equation: So the value of m' is expanded into $m' = m_0 + m_0 \frac{v^2}{2c^2}$ —.

Now is a good time for Einstein's snail to draw in its head under its shell, for if $v = c$ in the expanded form $m' = {}^3/_2\, m_0$. This shows the danger of throwing away higher powers so freely used by relativitists.

We do not so much blame them for refusing to spoil a good thing when they have it. But we do blame them for the deceiving use they make of this expanded value. They say the second term $m_0 \frac{v^2}{2c^2}$ is of the mechanical form for energy, and if it is energy, in order that the equation may be homogeneous, the first m_0 must also be energy. So the mass of all bodies is energy, whatever that may be. The "warp" in their logic is that $\left(1 - \frac{v^2}{c^2}\right)^{1/2}$ is coefficient of m_0, hence the two expanded terms are both m_0. If all matter is just energy that is another question not involved in this case.

(c) Time, in a moving system, has the Lorentz coefficient. They prove to their satisfaction that if two systems are moving relatively that the clock on one system is slow relatively to the clock on the other in the ratio of $1 : \left(1 - \frac{v^2}{c^2}\right)^{1/2}$.

We have already become accustomed to the outre things that relativitists evolve out of that coefficient, such as Eddington's "cruising around with the velocity of light and achieving immortality," but we have not had anything more "queer" than the following illustration by Einstein. "Give a watch a very large velocity (approximately the velocity of light) so that it travels with uniform speed; after it has gone a long distance give it an impulse in the opposite direction so that it returns to its starting point. We then observe that the hands of this watch during its entire journey to and fro have remained practically at a standstill, while the hands of an exactly similar watch which did not move with respect to the co-ordinate system (the sun or earth) have changed their position considerably. We must add: what is true for our watch with respect to the time must also be true for any other enclosed physical system, whatever its nature. The watch was used simply as a representative of all physical actions or occurrences. Thus, for example, we could substitute for the watch a living organism enclosed in a box. Were it hurled through space like the watch, it would be possible for the organism after a flight of whatever distance to return to its starting point practically unchanged, while an exactly similar organism which remained motionless at the starting point might have given place to new generations. For the organism in motion, time was but a moment if its speed approached that of light.

"THIS IS A NECESSARY CONSEQUENCE OF OUR FUNDAMENTAL ASSUMPTIONS AND ONE WHICH OUR EXPERIENCE IMPOSES UPON US"

This fable makes a considerable drain on our curiosity, not to mention our credulity. So we are disposed to examine somewhat critically the bases upon which Einstein rests his illustration:

First. "It is a necessary consequence which our experience imposes upon us." What experience of ours imposes this consequence upon us? We have little experience of even small uniform motion, and certainly less with velocity of bodies moving with velocity of light. Do the watch balances of the railroad engineers vibrate more slowly when the train is moving, at least have we had "experience" with an appreciable slowing from which we can predict that the balance spring in Einstein's box would cease to vibrate? Has our experience with heart beats warranted us in predicting that heart beats would cease in Einstein's box?

Second. "It is a necessary consequence of our fundamental assumptions." Here he is on safe ground. A shrewd man with a free rein for assumptions can do wonders. Einstein's principal assumption is that the watch in the box is to run slower than the watch on the earth in the ratio of $1 : 51 - \frac{v^2}{c^2}$.

Even if we grant Einstein all the fundamental assumptions he will have some trouble with his outfit when it gets back to the starting point and tries to be normal again.

(a) He has assumed that the watch moving with velocity of light has infinite mass. (b) He has assumed that a body moving with velocity of light contracts into nothing. (c) His assumption will prove that a watch moving with velocity of light will run infinitely slow. Therefore his watch has infinite mass, is infinitely small and is running infinitely slow. The man and the box have also absorbed as many infinities as possible. (d) Einstein's pet assumption is that of "equivalences." That assumption is that if we have two relatively uniformly moving systems, all occurrences and events on one system are exactly equivalent to those on the other. Why then are not events on the earth exactly equivalent to those in the box and vice versa?

We have traced relativity's claims, perhaps in a too critical vein. We have not, however, questioned the possibility of an observer on a moving system being fooled as to what is going on in another system, and writing down the amount of it in an equation. We have allowed Carmichael to prove that an observer is deceived about his time because he is deceived about his distance, and then turn about and prove that he is fooled about his distance because he is fooled about his time. Why criticise playful things too seriously?

We have not taken part in the debate as "What is a circle? A circle is drawn on paper in the usual way with a pair of compasses. An observer s, who believes the paper to be moving through the ether with great velocity supposes that the distance between the points of the compasses changes as the curve is described, while another observer s′, who believes the paper to be at rest in the ether will think it to be a circle.

"There is no experimental means of finding out which is right. We must admit that the same curve may be arbitrarily regarded as an ellipse or a circle."

Again; we have been duly surprised that we never thought of "drawing a circle with a heavy particle at the center," and finding that the circumference will be a little less than π times the diameter. We do not defend Euclid when relativity convicts him of error for not knowing that "a circle drawn on a sphere has its circumference less than π times the diameter if we measure along the surface of the sphere."

These and other like deplorable lapses of Euclid are indefensible. To fail to call a cone or the surface of a sphere a circle was a great mistake.

Relativity as unfolded by Einstein and his predecessors and followers is a wonderful exhibition of a sustained mathematical and metaphysical diversion, a wonderful exhibition of gymnastic skill on the part of some of its most prominent exponents in being able to be on both sides of a proposition on occasion. We are sometimes disappointed that relativity accepts as true the mistaken conclusion reached by one of the occupants of the moving system. We understand it better when we read: "The relativity standpoint is that we do not know and do not care whether the measures under discussion are 'true' or not."

We are rather gratified, when, after the most earnest endeavor on our part to see wherein Einstein had solved the mystery of gravitation, we were unable to find either an explanation or a law, to discover that Eddington, his most prominent advocate, reaches the same conclusion. He says: "In this discussion of the law of gravitation, we have not reached any ultimate explanation of its cause. A certain connection between the gravitational field and the measurement of space has been postulated, but this throws no light on gravitation. The relativity theory is indifferent to hypotheses as to the nature of gravitation, just as it is to hypotheses as to matter and light. It may not be an unobtainable hope that some day a clearer knowledge of the processes of gravitation may be reached, and the extreme generality and detachment of the relativity theory may be illuminated by the particular study of a precise mechanism."

Very disquieting is the final statement made by Einstein himself that the much heralded triumphs of relativity are not conclusive, but the crucial test is yet to be made. "If the displacement of spectral lines toward the red by the gravitational potential (in the sun) does not exist, then the general theory of relativity will be untenable."

Eddington, already quoted, makes it a little more emphatic. "A displacement of the Fraunhofer lines is a necessary and fundamental condition for the acceptance of Einstein's theory. If it is really non-existent we should have to reject the whole theory based on the principle of equivalence."

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